ICAR

Progress on White Grubs Research in India

Edited by

G. K. VEERESH

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EDITORIAL

Compiling information on the progress on white grub research in India was prompted at the conclusion of white grub workshop held at Jaipur in 1979. It was felt that there was need to bringout a proceedings of the progress made by different ICAR Adhoc projects on white grub. Thus all the principal investigators were requested to contribute a writeup of their respective projects work. A note by the ICAR Scientist (PP) is also added to give an idea of the genesis of research on white grubs initiated by the ICAR. A vast amount of Indian literature on white grub has accumulated, whose review has not been included in this for the obvious reason that it was beyond its scope. However an upto-date compendium of literature on Indian white grubs is provided, which would serve as a basis for all future research and extension on any aspect of white grub.

Although several interesting photographs were available on the biology, behaviour and control of white grubs, they could not be included for want of funds. Some drastic edition had to be affected to keep the size of the proceedings within the means and also to avoid duplication of information although at some places, the same aspect is repeated because the research was carried out simultaneously at different locations.

The ICAR provided the necessary financial grant to bringout this proceedings.

It is hoped that this would be a precursor for a complete book on white grubs of India and their management.

November, 1981

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ICAR AND WHITE GRUB RESEARCH IN INDIA

G.C.Tewari and T.P.Sriharan
I.C.A.R. Krishi Bhavan, New Delhi

White grubs are of world wide importance as serious polyphagous pests and cosmopolitan in occurrence. In India the white grub problem was realisted in early sixties and by now they have assumed a serious pest status of a number of crops particularly in the states of Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Gujarat, Punjab, Haryana and Bihar. In many regions endemic pockets have developed and the damage caused by them has increased enormously. These are spreading fast to adjoining areas and the problem is becoming more acute with intensive farming system based on increased irrigation.

Realising the importance of white grub problem in the country, the Indian Council of Agricultural Research constituted a Working Group of scientists engaged in white grub research in 1973 to discuss various facets of this problem. The first meeting of the Group was convened in New Delhi on March 16, 1974 under the chairmanship of Director General, ICAR. As a result of deliberations and discussions, control measures were chalked out and made available to the Plant Protection Advisor to Government of India for recommending to various State Departments of Agriculture. The Group also realigned the priorities of future research in the country.

Based on the recommendations of the Working Group, the following research schemes were sanctioned by the ICAR in

order to fill up the gap of existing knowledge in the field of White grub research:

1. Studies on White grub and its control - Agricultural Research Station, Durgapura, Jaipur.
2. Scheme for the research on White grub infesting important crops in Maharashtra State - MPKVV, Kolhapur.
3. Integrated control of White grub - University of Udaipur, Jobner.
4. Bio-environmental studies on White grub - I.A.R.I., New Delhi.
5. Larval taxonomy of Melolonthine beetles - U.A.S., Bangalore.

The technical programme for the above listed projects was carefully allotted with a view to carry out specific research required to fill the research gap and also to cater to the needs of particular locations.

Mid-term appraisal and evaluation of findings:

The annual research findings of the above projects were assessed by the Entomology/Nematology Panel of the ICAR for their merits. The suggestions of the Panel were communicated to the workers to improve upon and the control technology generated out of research was passed on to Extension Department from time to time for adoption. In order to disseminate the research findings a "White Grub Newsletter" was started which has recently been merged with Soil Biology and Ecology News-

letter. In this way the workers are well informed about the latest findings.

In order to avoid duplication and [illegible] coordination the Mini Workshops were organised by the ICAR where the scientists working on above projects was invited for deliberations. First Mini Workshop on White grub was held at Marathwada Agricultural University, Parbhani in May 1977. In this workshop the findings of different centres were reviewed. The second and third Mini workshops in the series were organised respectively at University of Agricultural Sciences, Bangalore (April 1979) and Agricultural Research Station, Durgapura (May 1980).

White grub control around complete farming system:

In early seventies the white grub posed a threat to the cultivators in Marathwada area of Maharashtra State. Three endemic pockets developed and the same were spreading fast to the adjoining areas. The position forced the ICAR to constitute another small group of experts to survey the endemic pockets and examine the cause for the spread of this pest in the State. The Group felt the need for investigations on integrated control approach of white grub on community basis with major emphasis on the cultural, mechanical, physical and biological methods of control. Accordingly, one plan project entitled "Operational Research Project" with complete farming system around Jowar with special emphasis

on endemic areas of white grub in Nanded district of Maharashtra was sanctioned by the ICAR to Marathwada Agril. University. Under the project the work was to be dealt with three dimensional facets i.e. i) development of technology to improve jowar production with special emphasis on white grub control, ii) testing of this technology for its economic viability by demonstrating it on the farmers' field and iii) identification of constraints operative in the acceptance and adoption of technology.

All India Coordinated Research Project on White grub:

With the objective to undertake multilocational and coordinated research on the survey, distribution, identification, bioecology of various forms of white grub pests attacking field crops and vegetables, with ultimate aim of developing simple, economical, safe and practical control of the pest, an All India Coordinated Project on White grubs has been cleared by the Planning Commission for Sixth Plan Period. The project has come into operation with effect from April 1, 1980 in the following centres. The budget is shown against each centre, involving Rs.13,74,709/- for the period 1980-83.

1. Coordinators cell, Parbhani	.. Rs.1,37,360/-
2. MAU, Parbhani	.. Rs.3,38,538/-
3. UAS, Bangalore	.. Rs.1,41,584/-
4. APS, Durgapura	.. Rs.1,08,536/-
5. SKN College, Jobner	.. Rs.3,91,939/-
6. MPKVV, Rahuri	.. Rs.2,61,752/-
Total	.. Rs.13,74,709/-

TAXANOMY, BIONOMICS AND CONTROL OF WHITE GRUB

G.K. VEERESH*.

Introduction

The adults of root grubs or white grubs are generally known as Chafers, Maybeetles, June beetles (Melolonthinae and Rutelinae; Coleoptera) all over the world. The problem of root grub damage to cultivated crops, lawns, forest plantations is world wide and considered as one of the major insect pests. In India these are found in every state. No plant is completely resistant to the attack of root grubs. The species belonging to the genus Holotrichia are destructive in the Indian sub-continent and more than one hundred species of Holotrichia have been recorded from India (Frey, 1971). Species belonging to this genus, damaging cultivated crops, have been collected from upper Simla Hills at above 3000 m.MSL upto coastal Kerala and from Arunachal Pradesh to coastal Gujarat.

The most important and widely distributed species is Holotrichia serrata F. which is recorded from all over India and next in importance is consanguinea destructive in Northern India. They damage all cultivated crops like cereals, millets, pulses, oilseeds, vegetables, sugarcane,

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tobacco and plantation crops. Some species are confined to certain agroclimatic regions, for e.g. H.nilgiria is confined to all coffee growing areas; Leucopholis species are found in all areca growing areas, whereas Anomala species are scattered all over India.

Other common species found in India are H.farinosa, H.sculpticollis (Western Ghats); H.reynaudi, H.rufoflava, H.heterotincta, (all over India); H.longipennis(Eastern India).

The adults of different species of white grubs vary in size and colour but all the larvae look alike. The grubs make no distinction between the roots of various plants while feeding, the adults of different species have some preferred hosts like neem (H.serrata) drumstick (H.insularis), tamarind (Schizonycha ruficollis); Khejari (H.consanguinea), some like Leucopholis species are not found feeding on any host..

The systematic position of Indian Scarabeids is in much shamble. The earlier identified Scarabs are locked up in many European muscums and most of the material is inaccessable to the systematists in India. Even the literature on Scarabaeids, particularly of Brenske and Burmeister who have contributed most to the Indian Scarbaeids is more

than a century old and is solely based on external morphological characters for forming Keys to separate species. Arrow (1917) has compiled a few groups like Rutellinae, Dynastinae, Cetoninae, Copri[illegible] in the Fauna of British India under their respective titles. The rest including melolonthinae remained in scattered literature. Gardner (1935) attempted to give a pictorial key to the immature stages of Scarabaeoidea. Ritcher (1961) described some North Indian Scarabaeid larvae. Recently, Frey (1971) has taken male genitalia as the basis for separating species which is more dependable and accurate. Consequently, the older identification needs revision in the light of genitalia characters.

Attempt has been made to provide keys for separating families of the Super Family Scarabaeoidea based on adult and larval characters. Only three families including Passalidae, Leucannidae and Scarabaeidae are considered following Ritchers classification (1966). All other families considered by Arrow (1946), Gardner (1935), IMMS (1971) are taken as subfamilies under the family Scarabaeidae, retaining Passalidae and Leucanidae in their original family level.

A representative characterisation of larva for each of Passalidae, Lucanidae and Scarabaeidae is given to introduce the beginners into the subject of larval Taxonomy of Scarabs. Keys to classify the subfamilies is given only for the family Scarabaeidae.

While forming Keys to separate subfamilies of the family Scarabaeidae, only the subfamilies in which, examples are available, are included. Thus seven subfamilies could be considered here, although 12 to 14 subfamilies are known under the family Scarabaeidae (Ritcher, 1966).

The subfamily Melolonthinae is further classified into tribes, genera and species but limited to the species reported here. Under the tribe Melolonthini, Key is given to all the genera of the tribe although two general Neodontocnema Arrow and Hoplosternus Guer are not represented here.

A brief summery of an extensive study on the bionomics and control of Holotrichia serrata F. carried out for over a decade is also presented.

Super family: SCARABAEOIDEA

One of the most distinct groups of insects, very widely distributed, found in varied habitats, are the beetles belonging to this super family and can be easily separated by their following characters.

Adults are primarily fussorial and the burrowing habit persists in majority of species. They are stoutly built, active fliers, sexes distinct, antennae ten segmented, the last three forming a lamellate club, thus they take their name "lamellicorn" beetles. Fore tibia dentate with one apical spur. Eighth abdominal tergite form an exposed pygidium.

The larvae are easily recognised and exhibit great similarity, they are broad, fleshy, whitish or greyish white and the body is curved in the form of letter 'C' and they are called "Scarabaei" form larvae. Legs well developed but rarely used for locomotion. Majority of species lay upon back or side in the midst of plenty of food. Head large, hypognathus strongly sclerotized; antennae 2-5 segmented; epicranial suture well developed, frontal suture asymmetrical; mandibles well developed powerful and exposed; maxillae terminate either in 1 or 2 lobes. Thoracic segments short closely held, bringing legs together. Prothorax and first eight abdominal segments each bear a pair of "Cribriform" spiracles. Last 2 to 4 abdominal segments are inflated, much large. The ventral surface of the 10th abdominal segment referred as raster often possess spine-like setae.

According to Imms (1977) the super-family scarabaeoidea is further divided into six families including Passalidae, Leucanidae, Scarabaeidae. Trogidae, Acanthoseridae and Geotrupidae. However, Ritcher (1966) has retained only three families including Passalidae, Leucanidae and Scarabaeidae. The present work is based on Ritcher's classification. The families Trogidae, Acanthoseridae and Geotrupidae of Imms have all been brought under the family Scarabaeidae in Ritcher classification and these have been given the status of subfamily. In addition to these three, he has included another nine subfamilies under the family Scarabaeidae.

The three families under the super-family are classified based on the following characters.

(a) Key to the families of the super-family Scarabaeoidea based on adult characters.

Leucanidae: Adults with antennae geniculate or elbowed, club loose, not capable of rolling up; (Fig. 1) promentum entire; ligula inserted dorsally.

Passalidae: Antennae not elbowed or geniculate, club segments held closer to one another, (Fig. 2) promentum emarginate, ligula inserted at apex.

Scarabaeidae: Antennae not elbowed, eight to 10 segmented the joints of the club very thin and closely adopted (Fig. 3).

Key to the families of the superfamily Scarabaeoidea based on the larval characters: (Ritcher (1966) classification)

1. Mandible without a ventral process, antenna two segmented. Maxillary palpus three segmented. Thoracic spiracles with emarginations of respiratory plates facing anteriorly, those of abdominal segments facing posteriorly metathoracic legs greatly reduced in size, unsegmented ..... Family PASSALIDAE

2. Mandible with a ventral process, antenna with three, four or apparently five segments. Maxillary palpus four segmented. Thoracic spiracles with emarginations of respiratory plates facing anteriorly, cephaloventrally, posteriorly, caudoventrally or ventrally; those of abdominal segments facing anteriorly, cephaloventrally or ventrally but never posteriorly. Metathoracic legs normal or reduced in size; if reduced in size with two or more segments.... 2

2. Maxillary stridulatory teeth usually absent, if present, then the distal segment of the antenna greatly reduced in size. Anal opening longitudinal or Y shaped, usually lying between two oval lobes. Stridulatory organs present on meso and metathoracic legs. Legs always normal in size ..... Family LEUCANIDAE

Maxillary stridulatory teeth usually present; if absent, then the distal segment of the antenna not greatly reduced in size. Annal opening transverse, angulate or Y shaped. Stridulatory organs present or absent on legs. Legs may be reduced in size .....Family SCARABAEIDAE

A brief biological note on the families of Scarabaeidae

1. Lucanidae: (Stagbeetles):

Adult: (Fig. 4) Moderate to large sized 10 to 50 mm long beetles. The stag beetles are familar on account of the great development of the mandibles in the males which in some cases attain a length equal to that of the rest of the body. The males are usually much larger than those of the other sex and exhibit great variation in size among the individuals of the species. The antennae are geniculate with the club loose; the prementum is entire; the abdomen is covered by the elytra, but the latter are almost always devoid of longitudinal striae, scutellum visible; there are five visible abdominal steriites. Colour dull brown, or black or metalic; general surface of the body without setae.

Larva: (Fig. 5) Larvae of lucanidae are 'C' shaped and whitish or blueish in colour live in damp and decaying wood. They resemble larvae of scarabaeidae in possessing cribriform spiracles. The antennae, epipharynges, and maxillae single lobed and show morphological similarities to those of the less specialized scarabaeidae on the other hand, mandibles and hypopharynges of lucanid larvae are similar to those of the higher Scarabacidae. In general, based on larval characters the lucanidae are much more closely related to scarabacidae than are the passalidae. They differ from many scarabacid larvae in that the segments are not raised into three folds. The last pair of legs are not modified or reduced as in the passalidae.

PLATE: I

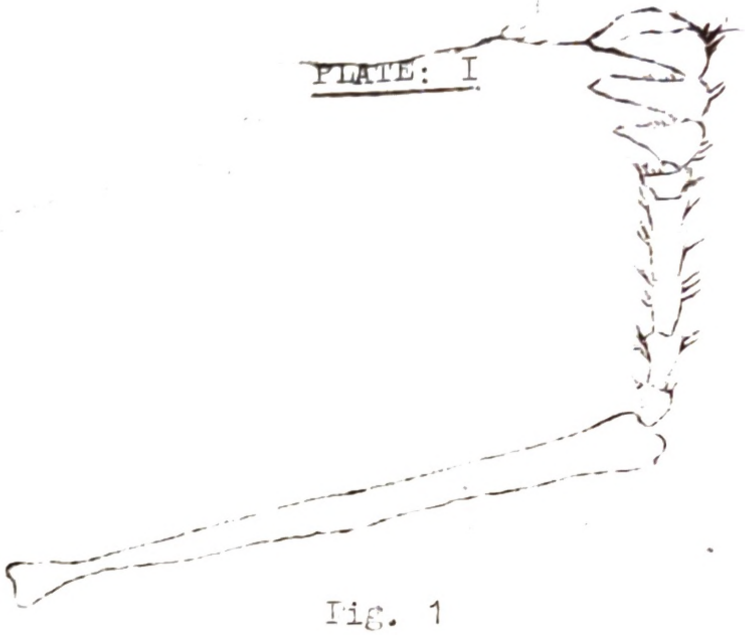

Fig. 1

Fig. 2

Fig. 3

PLATE: II

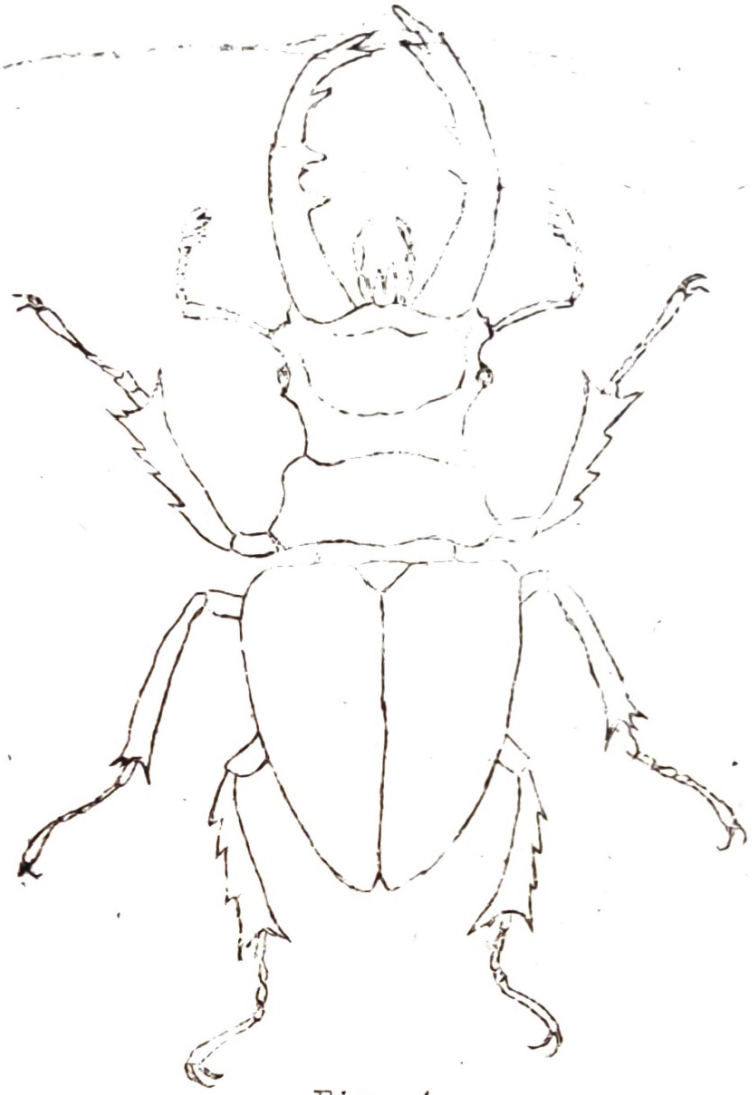

Fig. 4

Fig. 5

Larvae of lucanidae characterised as follows: antennae 3 or 4 segmented; last segment greatly reduced in size. Epipharynx with united tormae and usually with three mesia; mandibles with a ventral process. Maxilla with galea and lacinia distinctly separate, maxillary stridulatory teeth usually absent; spiracles cribriform and anal opening 'Y' shaped or longitudinal, lying between two fleshy lobes; Legs well-developed, not reduced in size and possessing stridulatory organs on the meso and meta thoracic legs.

2. Passalidae:

Adult: (Fig. 6) These beetles live in half decayed logs and stumps in company with their larva and are of particular biological interest because of their social habits. Larvae and adults live together in colonies and communicate with each other by stridulating, the adults tending the larvae in the brood galleries. The members of this family are somewhat flattened, parallel sided, black or dark brown shiny. The elytra cover the abdomen and are deeply longitudinally striated and the mandibles are not specially developed in the males. There are five visible sternites; antennae not geniculate and the club segments are not closely opposed. The mandibles have a movable dorsal tooth and the prementum is daply emarginate.

Larva: (Fig. 7): The larvae are more elongate, sub-cylindrical, dull white or greyish. They are more active and have the first two pairs of legs relatively long; the third pair are greatly modified, each leg being reduced to a very short coxae and a more elongate

trochanter, which are used to scrape over a file on the coxa of the mid leg thereby producing a high-pitched sound.

Larvae of passalid may be distinguished as follows:

Antenna two segmented; mandible tridentate at apex; without a ventral process. Maxilla with galea and lacinia distinctly separate dorsal surface of the stipes with a patch of conical stridulatory teeth. Maxillary palp three segmented. Epipharynx symmetrical. Prothorasic spiracles with concavity of respiratory plate facing anteriorly; abdominal spiracles with concavities of respiratory plates facing posteriorly. Pro-and meso thoracic legs four segmented each with a long curved claw. Anal slit transverse.

Adults and larvae of Passalus sp. were collected in a rotting log during the month of October 1979 in a Coffee Estate at Somarpet, Coorg district. There were about 50 larvae associated with equal number of adults. The larvae collected were in 2nd and 3rd instar. The larvae were reared to adults in a piece of rotting log with the association of adults. Adults emerged after 13 weeks from third instar larvae. Pupal period was about 2 to 3 weeks. There was heavy mortality of larvae reared individually without adults.

Passalus spp.

Larvae of this species may be characterised as follows:

Cranium: (Fig. 8) Straw coloured or yellowish-brown, bare shining. Frons with 5-6 long setae; anterior frontal setae absent; antenna two segmented.

Epipharynx (Fig. 11):

Epipharynx with clythra, heptamerum poorly developed with few setae; heli absent, chaetoparia well-developed, curved with long chaetae, two sensilla located anterior to the crepis. Plegmata and propleg-mata are absent laeotorma and dexiotorma are present.

Mandible (Fig. 10):

Mandibles not well developed with Scissorial part for cutting, tip trifid, scrobis with one to two setae, dorsomolar region with four to five small setae.

Maxilla (Fig. 9):

Galea and Lacinia separate, lacinia with a bifur-cate apical uncus, maxillary stridulatory area borne on stipes with a patch of 20 to 22 conical projections, maxillary articulating membrane without granular spots.

Raster (Fig. 12):

Raster with a rather dense patch of short, caudally directed setae on the venter and posteriorly with a transverse row of 12 longer setae, lower and upper anal lips with sparse small setae.

3. Scarabaeidae:

They are commonly called Dafer or May-June beetles all over the world. Usually stout bodied insects, varying enormously in size, and chiefly dis-tinguished by having the lamellae of the antennae movable

and capable of being brought close together or separated; antennae [illegible]-11 jointed (usually 10 joints), club 3-7 jointed (usually [illegible], variable in form. First joint elongate, anterior [illegible] cavities large, transverse, closed behind, pygidium usually exposed; abdomen as a rule with six or (at the sides) seven visible segments; legs fussorial, but variable, tarsi 5 jointed, the anterior pair some times absent.

Larva:

Larvae live concealed, feeding on roots or decaying vegetable matter. Some are termitophillus. Larvae white or greyish, with well-developed, pale reddish-brown head and with three pairs of legs, the hind pair being fully developed and usually longer than the middle legs; antennae four segmented. Larvae are rarely able to stridulate.

Maxillary stridulatory teeth usually present; if absent, the distal segment of the antenna not greatly reduced in size. Anal opening transverse, angulate or Y shaped. Stridulatory organs present or absent on legs. Legs may be reduced in size.

According to Ritcher (1966) the family Scarabacidae has 12 sub-families. Some authors have included 10 sub-families (Dillon, E.S., 1961; Imms, 1977) but (Fowler 1912) has considered only seven sub-families under the family Scarabacidae. However, only five sub-families including Melolonthinae, Scarabaeinae, Cetoniinae, Rutelinae and Dynastinae are represented by large number of species under South Indian condition.

PLATE: III

Fig. 6

Fig. 7

PLATE IV

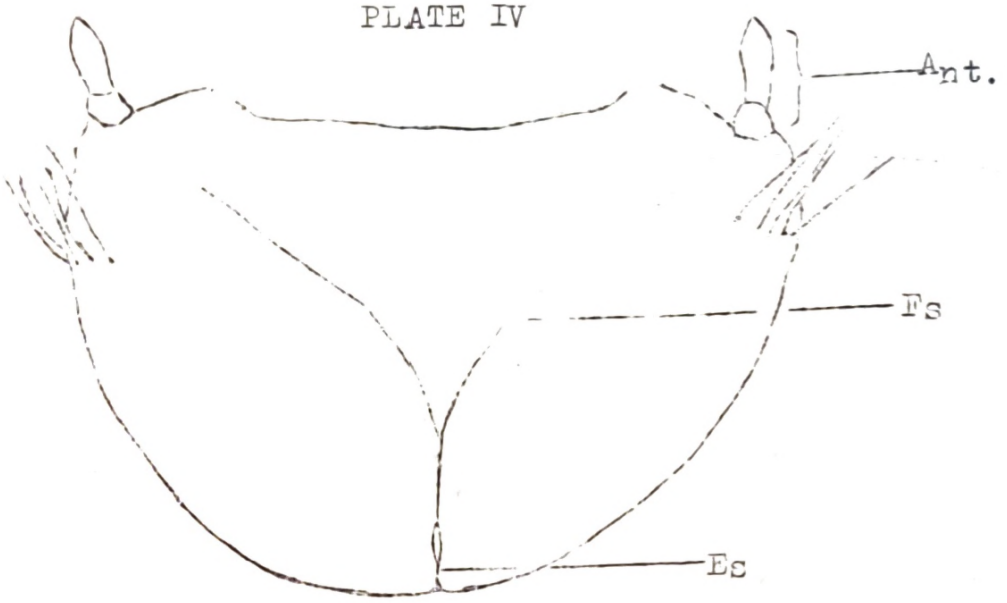

Fig.8

Fig.9

Fig.10

PLATE V

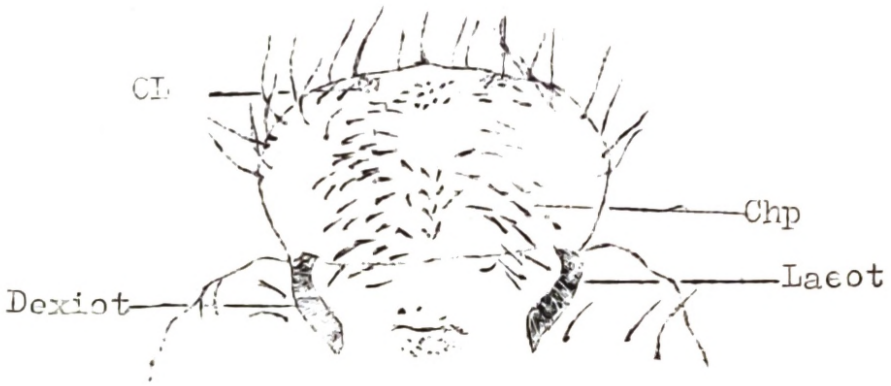

Fig.11

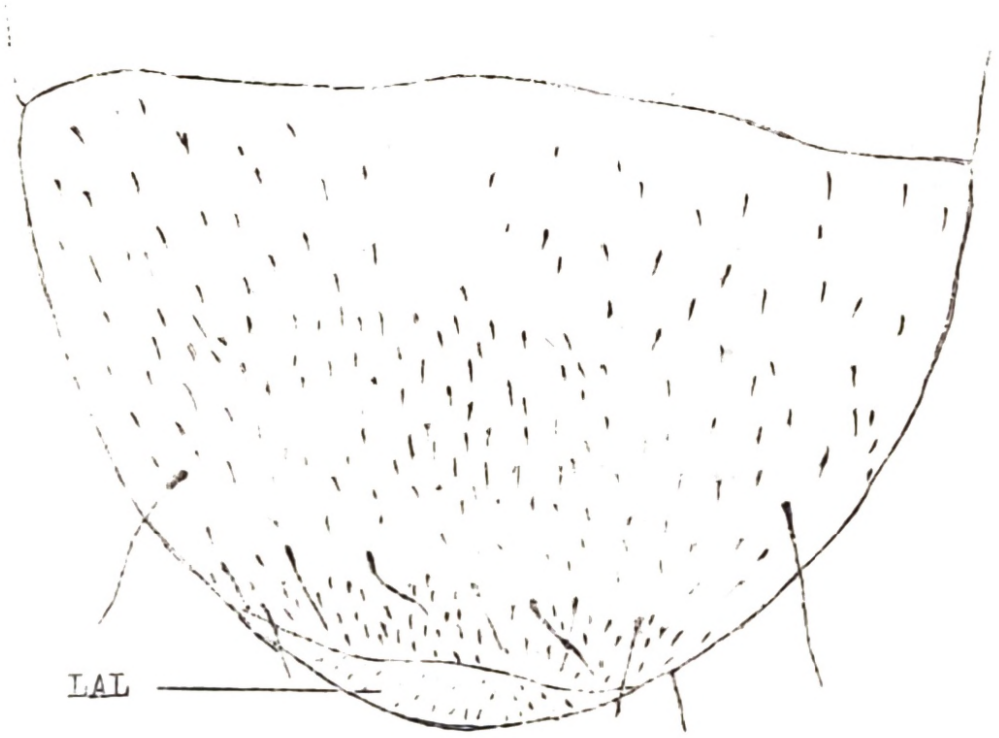

Fig.12

PLATE: VI

Fig. 13

Fig. 14

Fig. 15

Fig. 16

Fig. 17

Fig. 18

Fig. 19

The members of the sub-family Aphodiinae are highly attracted to light and their habitat is mostly dung. The true dung beetles (Scarabaeinae or Coprinae) are not phytophagus both in the adult and in the larval stage and are considered important in incorporating dung into the soil. The Dynastids breed in decaying organic matter including dung and occasionally the larvae are reported to feed on plant roots. Some adults like rhinoceros are phytophagus and are of great economic importance. The cetonids breed in organic debris and leaf mulch, but the larvae are not known to feed on plant roots. The adults are commonly called 'Rose chafers' and highly destructive to roses and other members of Rosaceae and Rutaceae during May-June. They are mostly brightly coloured, metalic green to blue and reddish-brown.

The members of the sub-family Melolonthinae and Rutelinae are phytophagus either in adult or larval stage or both. Some of the worst pests recorded as root feeders from several parts of the world come from these two groups. The European chafer and the Japanese beetle under the sub-family Melolonthinae and Rutelinae, respectively, have made their history in the Western hemisphere. The members of the genera Holotrichia and Anomala of Melolonthinae and Rutelinae, respectively, are well known pests in the Indian sub-continent feeding on almost every crop under all situations except in puddle conditions.

Several hundreds of species in the sub-family Melolonthinae are known to cause damage to one or the other plant either in the adult or larval stage

or both in this country. They are highly destructive to crops like sugarcane, groundnut, vegetables, pulses, plantation crops, forage crops etc., (Veeresh, 1977, 1979, 1980, 1981). The beetles invariably emerge after the first rains in summer almost from March to July in this country depending upon the first rains. They tend to congregate, after emergence at dusk, on some selected adult hosts like neem (Azadirecta indica), acacia (Acacia arabica) Prosopis sp. zyzipus sp. etc. The mating takes place immediately after emergence and lasts for 5-10 mts. the adults may be active throughout night and get back into the soil before dawn or any time of the night. This is the only time the adults make their appearance outside of the soil, the rest of the life being spent within the soil. Eggs are laid singlly, some in earthen cells, 2-3 inches below the soil. Eggs pearly white and turn their shape from oblong to round in 3-4 days, hatch in 10-20 days. The larvae undergo three moults with three instars, and the larval period last from 80 to 300 days. The first instar feed on the organic matter, subsequent instars feed on live roots. They can exist in any situation except in hard gravelly soil or under inundation. Before pupation, larvae go deeper and pupate in earthen cells. Pupal period lasts for 10-20 days. The adults, formed within the earthen cells remain from three weeks to six months in the soil until the first summer rains when they come out of the soil.

KEY TO THE SUB-FAMILIES OF SCARABIDAE RECORDED IN THE REPORT BASED ON ADULT BEETLES

1. Antennae telescoped, labrum and mandibles visible from above, flattened, strongly produced, mandibles not toothed ..... RHYSORINAE

   Antennae not telescoped, mandibles toothed, Labrum and mandibles may or may not visible externally 2

2. Hind tibia with one apical spur, middle coxae widely separated ..... SCARABAEINAE

   Hind tibia with two apical spurs, middle coxae not widely separated 3

3. Mandibles visible externally, front coxae transverse, deeply embedded in the thorax ... . DYNASTINAE

   Mandibles not visible externally, front coxae otherwise 4

4. Pygidium not exposed, Labrum and mandibles reduced and concealed ..... APHODIINAE

   Pygidium exposed, Labrum and mandibles well developed 5

5. Epimera of mesothorax visible from above, clypeus emarginate laterally, antennal insertion visible from above ..... CETONIINAE

   Not as above 6

6. Claws equal, bifid, not movable, Epipluron absent ..... MELOLONTHINAE

Claws unequal, movable, epipluron present .... RUTELINAE

KEY TO SUB-FAMILIES OF SCARABAEIDAE ENCOUNTERED IN THE PRESENT STUDY BASED ON LARVAL CHARACTERS

1. Maxilla with galea and lacinia distinctly separate 2

Maxilla with galea and lacinia entirely fused or fused proximally but distally free or fitting tightly together 4

2. Distal segment of antenna may or may not be reduced in diameter compared to other antennal segment, body not hump backed, legs 4 segmented, claws well-developed 3

Distal segment of antenna much reduced in size, bod, strongly hump backed, legs 2 segmented, claws very small or absent, each bearing one or two setae ..... SCARABAEINAE

3. Anterior margin of labrum trilobed or broadly rounded if serrated or truncated. Prothoracic legs with no stridulatory organs ..... APHODIINAE

Anterior margin of labrum serrate or with truncate lobes pro and mesothoracic legs with stridulatory organs ..... HYBOSORINAE

4. Mandible with ventral stridulatory area absent, indistinct or consisting of a patch of minute granules. Anal opening usually angulate or Y shaped. Galea and lacinia fused proximally but separated distally or tightly fitted together. Last antennal segment always with a single, large, oblong, dorsal, sensory spot ..... MELOLONTHINAE

Mandible with a ventral, oval, stridulatory area consisting of a few to many transverse, granular ridges. Anal opening a straight or slightly curved, transverse cleft. Galea and lacinia of maxillae fused forming a mala. Last antennal segment with one or more dorsal sensory spots 5

5. Lacinia of maxilla with 1 or 2 well-developed terminal unci or uncus almost absent. Maxillary stridulatory teeth always with anteriorly projecting points, never truncate 6

Lacinia of maxilla with 3 well-developed terminal unci. Maxillary stridulatory teeth truncate or with anteriorly projecting points 7

6. Labrum symmetrical, either entire, bilobed, or trilobed. Epizygum absent. Epipharynx always with a single nesium (sclerotized plate absent), plegmata absent. Haptomerum often with a conspicuous, transverse, curved row of stout setae which may or may not be interrupted by a median process. If the lacinia has 2 terminal unci, then the 2 unequal in size ..... CETONIINAE

Labrum usually asymmetrical; episygum usually present. Epipharynx usually with 2 nesia and usually with plegmat . Haptomerum never with a conspicuous, transverse, curved row of stout setae. If the lacinia has 2 terminal unci, then the 2 usually equal in size .....
..... (TRIBES ANOMALINI AND RUTELINI) RUTELINAE

7. Plegmatia present, Haptomerum of epipharynx with a dense transverse row of 6 to 9 heli. Maxillary stridulatory teeth never truncate .....
..... (TRIBE ADORETINI) RUTELINAE

Plegmatia absent. Haptomerum of epipharynx with a raised, bi-lobed or tooth-like, or ridge-like process. Maxillary stridulatory teeth usually truncate ..... DYNASTINAE

SCARABAEINAE (COPRINAE)

Adult (Fig. 20): The beetles belonging to Scarabaeinae are small to very large round or oval, dung feeding beetles many species are black or purplish black but a few have brilliant metalic colours. The head of the males often bears a prominent median horn.

They are beneficial in incorporating dung and organic matter into the soil. They may be harmful as some species are known to serve as intermediate host, for parasites of domestic animals.

They are characterised by exposed pygidium, hind tibia with only one spur, mid coxae widely separated;

scutellum reduced or absent. The frontoclypeus is expanded to cover the mouth parts. Antennae eight or nine segmented, club three segmented. Abdomen with six visible sternites; fore tarsi sometimes absent.

Larva (Fig. 21): The larvae feeds on the faeces of higher animals. Larva hump backed, labrum symmetrical; distal margin trilobed. Medium of epipharynx surrounded laterally and anteriorly by phobae, chaetopariae each consisting of a very few stout setae or a patch of stout setae. Anterior part of haptolachus with a transverse sinuate mesophoba. Scissorial area of left mandible with three teeth and that of right mandible with two teeth; Galea and lacinia of maxilla widely separated, not fused. Hypopharynx with two asymmetrical sclerotized process termed oncyli. Antenna four segmented with the distal segment so reduced that it appears to be an appendage of the third segment. Last abdominal segment with several fleshy, lateral and caudal lobes. Raster with a teges or paired polystichous or monostichous palidia, anal slit transverse. Legs two segmented and bears one or two terminal setae. Claws minute or absent.

2. Aphodiinae:

Adult (Fig. 22): This sub-family contains a large number of species of small inconspicuous beetles and are mainly dung feeders. These are distinguished by their pygidium covered, mouth parts and labrum concealed beneath the frontoclypeus, hind tibia with two apical spurs, foretarsi normal and the scutellum visible.

Larva (Fig. 23): The larvae are coprophagus and some species of the genus Aphodius known to be injurious to the roots of grasses and other plants. Larvae of Aphodinae are characterised as follows.

Antenna four or apparently five segmented with the last segment reduced in size Epipharynx trilobed, pedium surrounded by phobae, galea and lacinia of maxilla distinctly separate but often close together legs four segmented with well developed claws. Anal lobes whitish or yellowish and bare of setae.

Aphodius insularis Bter

Larvae were collected in decomposed dung manure at Bangalore, and reared in the laboratory up to the adults stage. Larvae of this species may be characterised as follows:

Cranium (Fig. 24): Brown and smooth, anterior margin of frons bearing two setae. A single exterior frontal seta present on each side and posterior region bearing four setae in a transverse line; clypeo-frontal suture and frontal suture distinct; epicranial suture half to one of the frontal suture. Dorso-epicranial setae two in number on each side of epicranial suture.

Epipharynx (Fig. 25): Trilobed. Clythra present. Protophobae arranged in transverse row; Laeophobae and dexiophobae arranged in single row meeting protophobae anteriorly. Laeotorma and dexiotorma united with a prominent epitorma.

PLATE: VII

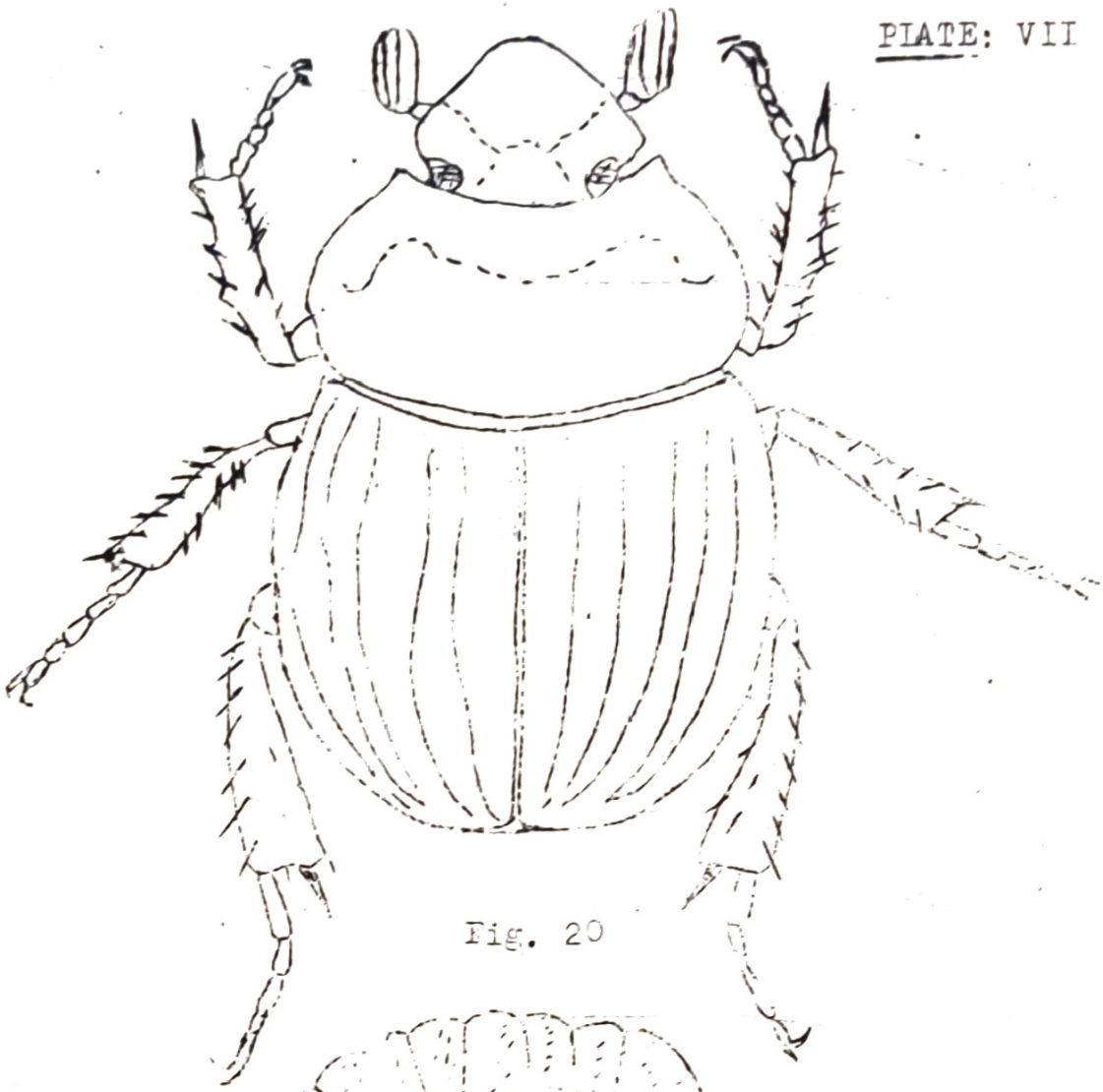

Fig. 20

Fig. 21

PLATE: VIII

Fig. 22

Fig. 23

Mandibles (Fig. 27): Scissorial area with distinct curved cutting edge, molar part of left and right mandible somewhat flat.

Maxilla (Fig. 26): Galea and lacinia separated. Galea furnished with a single uncus; lacinia with a shorter uncus and row of 6-7 pointed setae. Maxillary stridulatory teeth conical and 6-7 in number.

Raster (Fig. 28): Palidia absent. Tegillum composed of 45-50 hamate setae. Anal cleft transverse. Upper and lower anal lobes with two transverse pads and small triangular division between them.

3. Hybosorinae:

Adult (Fig. 29) Beetles 5 to 12 mm long, shiny dark-brown or black; mandibles sharply curved with pointed apices directed inwards towards each other and visible from the above beyond the strongly transverse labrum. Antennae telescopic (Fig. 30) ten segmented, club with the proximal segment circular and concave into which the two apical segments are closely fitted, abdomen with six visible sterites in male and five in female. Foretibia with three large and numerous small teeth; tarsi shorter than tibia. Adult and larve are associated with carcase. The larvae of hybosorinae are characterised as follows.

Anterior margin of labrum with three truncate lobes. Epipharynx with a row of setae on each chaetoparia, a blunt tooth in the haptomeral region and united torme. Maxilla with galea and lacinia distinctly

separate, maxillary stridulatory area consisting of a sparse row of [illegible] teeth. Antenna three segmented. Venter of last abdominal [illegible] with two palidia each consisting of a curved [illegible] outwardly directed setae. Legs four segmented with well [illegible] loped claws. Prothoracic and mesothoracic legs with stridulatory organs.

Hybosorus orientalis Westw.

Larvae were collected in and around Bangalore, they were found in root zone of Nepiar grass. Larvae reared to adults in the laboratory. Larvae of this species may be characterised as follows:

Cranium (Fig. 31): Brown in colour, narrower than prothorax anterior margin of frons furnished with 7-8 setae in single patch on each side. Posterior frontal seta long and be set with lateral margin of frontal suture on each side, clypeo-frontal suture frontal suture distinct epicranial suture about one half of one of the frontal sutures. Two darso-epicranial setae be set on either side of epicranial suture.

Epipharynx (Fig. 32): Consists of three apical truncate lobes flatened on either side with bulbous lobes, bearing eight setae. Haptomeral region furnished with 6-7 sensilla in a row. Right chaetotaxia furnished with 8-9 setae and left with 17-20 setae. Torme distinct and united.

Mandibles (Fig. 34): Light in colour and shorter than cranium. Scissorial area with almost straight cutting edge and limited with a scissorial notch. Molar structure of right and left mandible look alike.

PLATE IX

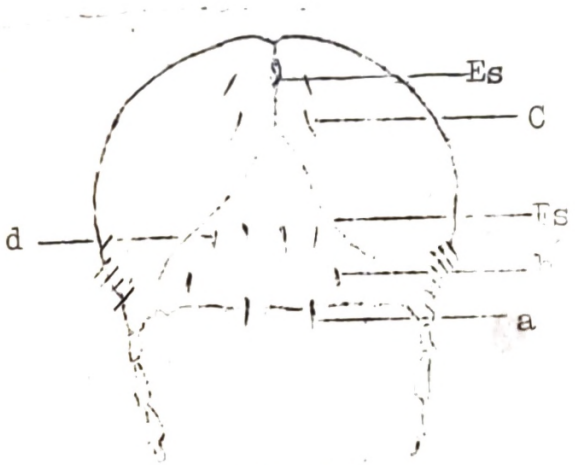

Fig.24

Fig.25

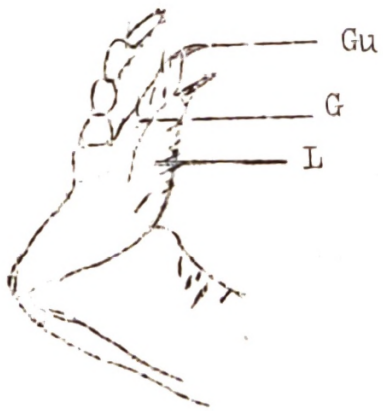

Fig.26

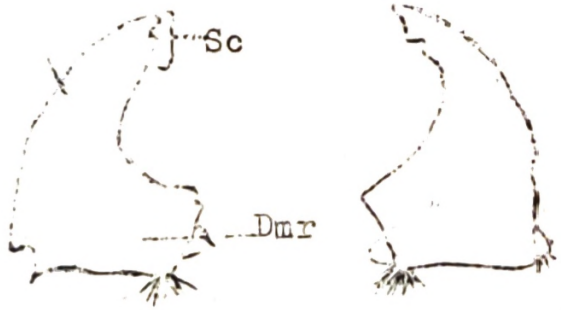

Fig.27

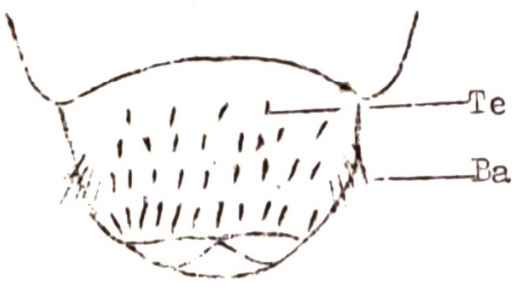

Fig.28

PLATE: X

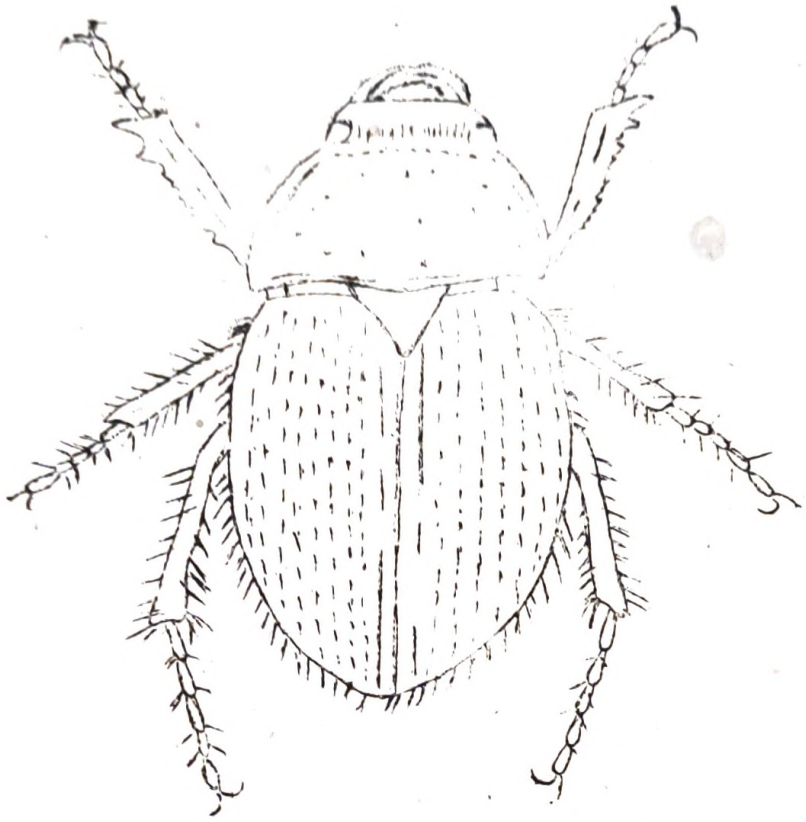

Fig. 29

Fig. 30

Dorsomolar region of left mandible furnished with 6-7 setae in vertical line that of right mandible with 9-10 setae in two patches.

Maxilla (Fig. 35): Cardo elongate, stridulatory area consist of sparsely set a row of about nine rather blunt conical teeth, three teeth located on palifer Galea and lacinea distinctly separate. Galea bearing a single stout claw-like uncus lacinial uncus rather short. A row of seven spine-like setae also present on its dorsal aspect.

Raster (Fig. 35): Consists of Palidia and tegillum; each palidia consists of curved rows of about 25-28 outwardly directed short depressed pali, Palidia meeting posteriorly. Tegillum furnished with 50-60 tegs.

4. Rutelinae:

Adults (Fig. 36) Beetles moderate to large size (8 to 35 mm) and stoutly built, colours usually bright and more or less metalic. The adults emerge after the dusk soon after the premonsoon showers and feed extensively on the foliage during night hours. Adults of a number of species are attracted to light.

Adults are distinguished from the allied subfamilies by having the tarsal claws unequal and movable; head and prothorax without horns or tubercles. The head, prothorax and hind body are very closely fitted together. The front coxae prominent contingueous and posternum may be elevated behind them. The middle

coxae usually also in contact, but in some species mesosternum projected between them, sometimes forming long pointed process.

Larva (Fig. 37): Larvae are typically scarabaei form feeding on roots and soil organic matter. They are characterised by [illegible] with a ventral oval stridulatory structure consisting of a number of transverse ridges; maxilla with a row of stridulatory teeth directing anteriorly; lacinia of maxilla with one, two or three unci. Haptomerum of epipharynx with two or more prominent heli. Epipharynx without proplegmata; plegmata present or absent; raster with or without palidia, anal slit transverse slightly curved.

- Mimela maclayana Burm.

Larvae reared from the adults collected at light in Coffee Plantation at Hemmige, Hassan district in October 1979. Larvae of this species are characterised as follows.

Cranium (Fig. 38): Cranium pale yellow, surface shiny, clypeo-frontal suture, frontal suture and epicranial sutures distinct, anterior frontal setae two, epicranium with two dorso epicranial setae.

Epipharynx (Fig. 39): Acroparia with few long setae, zygum and epizygum continuous, proplegmata absent, chaetoparia well-developed and covered with many setae; setae generally longer and pointed near the pedium and gradually weaker towards the plegm. Pedium oval Haptomerum with macro and micro sensilla in curved line.

PLATE XI

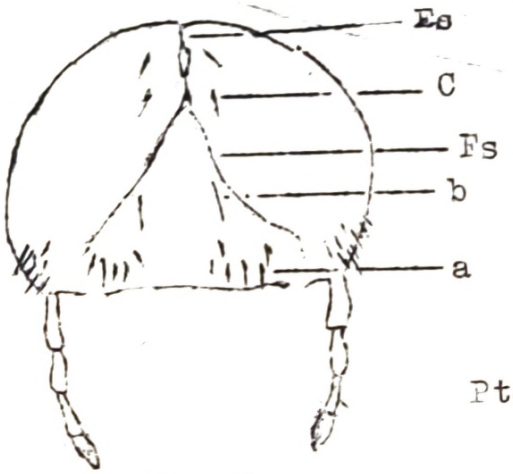

Fig.31

Fig.32

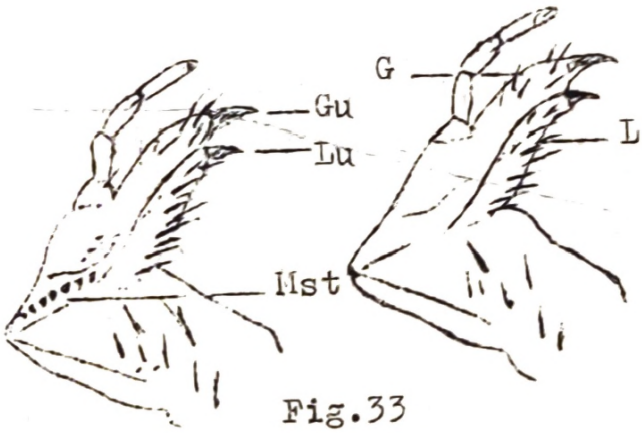

Fig.33

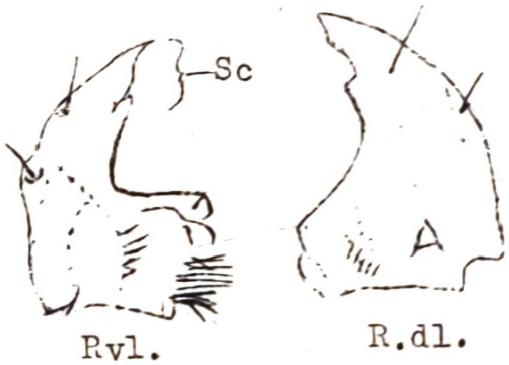

Fig.34

Fig.35

PLATE: XII

Fig. 36

Fig. 37

PLATE XIII

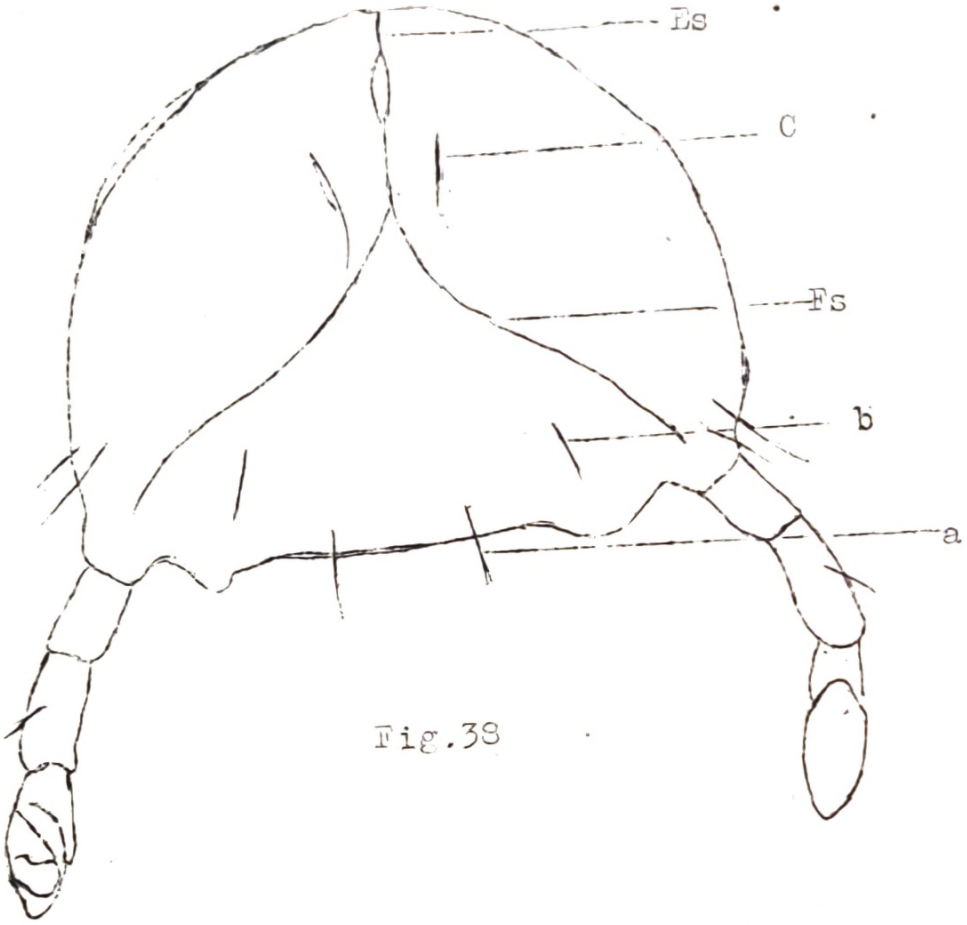

Fig.38

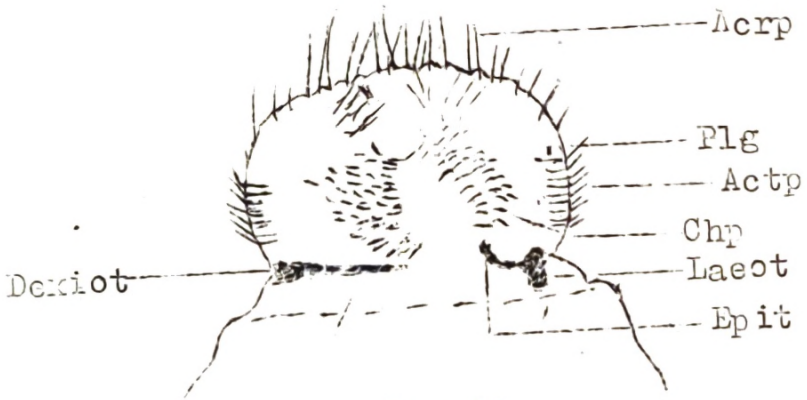

Fig.39

Fig.40

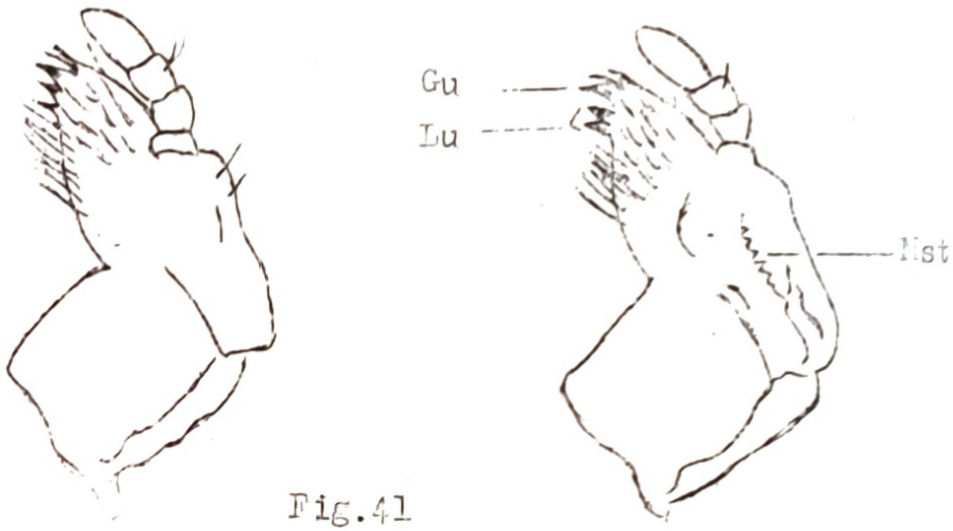

Fig.41

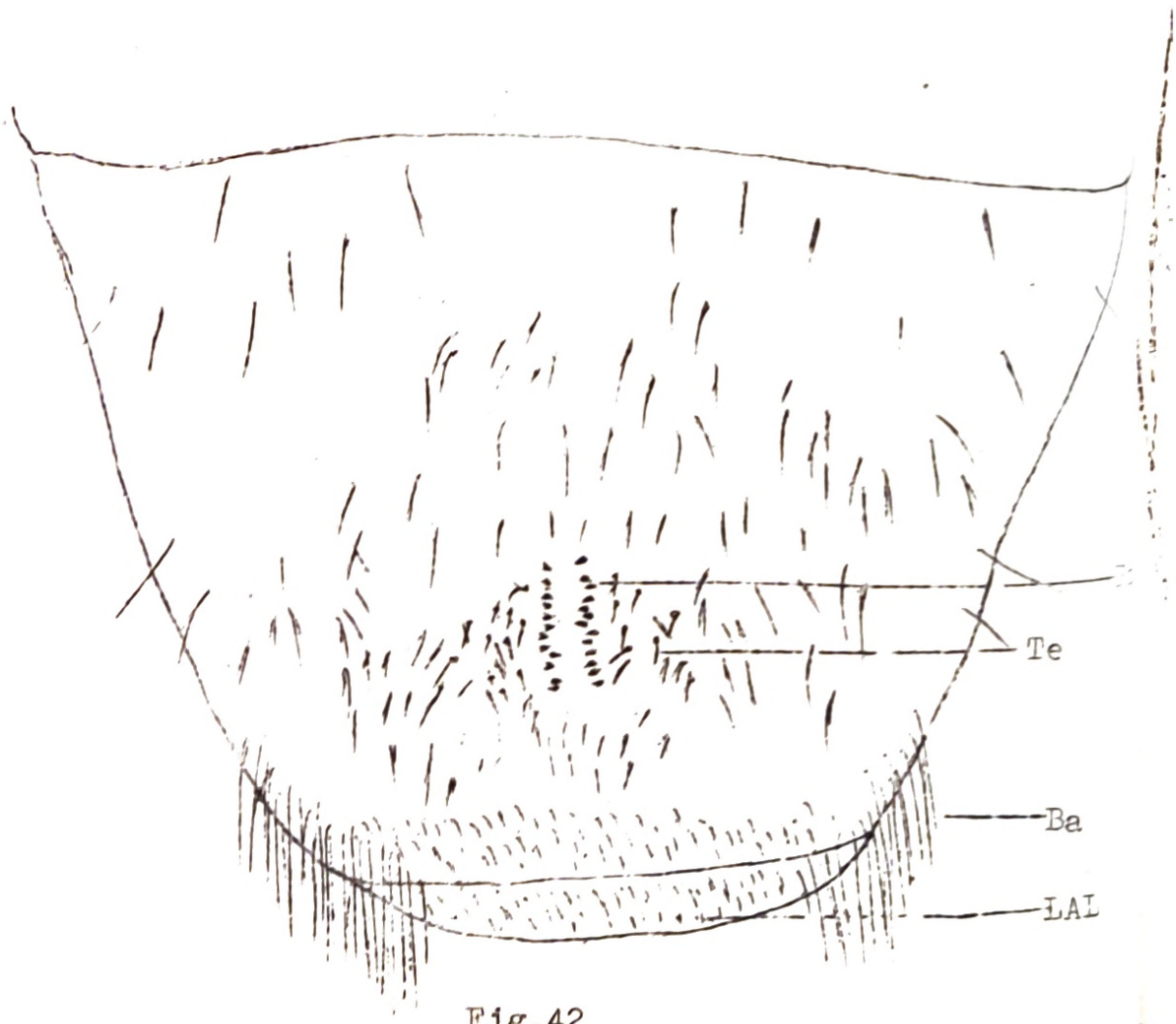

Fig.42

PLATE: XI

Fig. 43

Fig. 44

Fig. 45

Fig. 46

Fig. 47

PLATE: XVI

Fig. 48

Fig. 49

Fig. 50

Fig. 51

Mandible (Fig. 40): Scissorial part with a straight cutting edge, scrobi[illegible] eight to ten setae, stridulatory area [illegible] consisting of many transverse granular ridges.

Maxilla (Fig. 41): Galea and lacinia fused, galea with a distal large claw-like uncus, lacinia bearing two equal Unci stridulatory teeth apically pointed on stipes.

Raster (Fig. 42): Septula short. Each palidium composed of fairly slender, tapering and depressed pali, not arranged in straight line. Tegellum consists of stout setae; anal slit transverse.

3. Cetoniinae:

Adult (Fig. 52): Beetles moderate to large size (8-45 mm), rather depressed, flattened form; dull to brilliently coloured often with metalic or enamelled coloured. Diurnal in habit and feed on floral parts and tender shoots and breed in sandy type of soils with high organic matter, rotting logs, damplitter, compost etc.

The adults are characterised as follows:

Clypeus is always well-developed forming a broad shovel-like instrument and occasionally in both sexes. Fore coxae conical. Lateral edges of elytra with a concavity behind the shoulder which exposes metepimeron and the edge of the hind coxa from above, mesepimeron also visible from above the angle between pronotum and elytra.

Larva (Fig. 53): The food of cetonid larvae consists of organic matter in the soil, decaying wood or trash and other debris accumulated in the hollows of the trees and elsewhere.

The larvae are characterised as follows. Labrum symmetrical, mandibles each with a ventral oval stridulatory structure; maxilla with a stridulatory structure, maxillary stridulatory teeth with anteriorly directed points; plegmata and pro-legmata absent. Haptomerum of epipharynx frequently with a conspicuous transverse curved row of stout setae; lacinia of each maxilla with a single distal uncus or with two unequal distal unci fused at their bases; palidia present or absent. Anal slit transverse, often slightly curved.

Heterorhina elegance F.

Adults of this species were collected on brinjal plants in Sundapalli, Andhra Pradesh during August 1979. Adults were yielded eggs with deep litter and organic matter in the laboratory. Larvae reared from the eggs of these adults are characterised as follows:

Cranium: (Fig. 54): Smooth, yellowish-brown. Clypeo frontal suture and frontal sutures are distinct, anterior marginal region without setae. A post-frontal set near the concave margin of the frontal suture present, Dorsoepicranial setae two in number on each side of the epicranial suture.

Epipharynx (Fig. 55): Distinctly trilobed, anterior lobe furnished with four to five moderately long setae and indented in the region of epizygum; Clythra present; Haptomerum with a transverse row of moderately long and stout setae; Chaetoparia well-developed,

PLATE: XVII

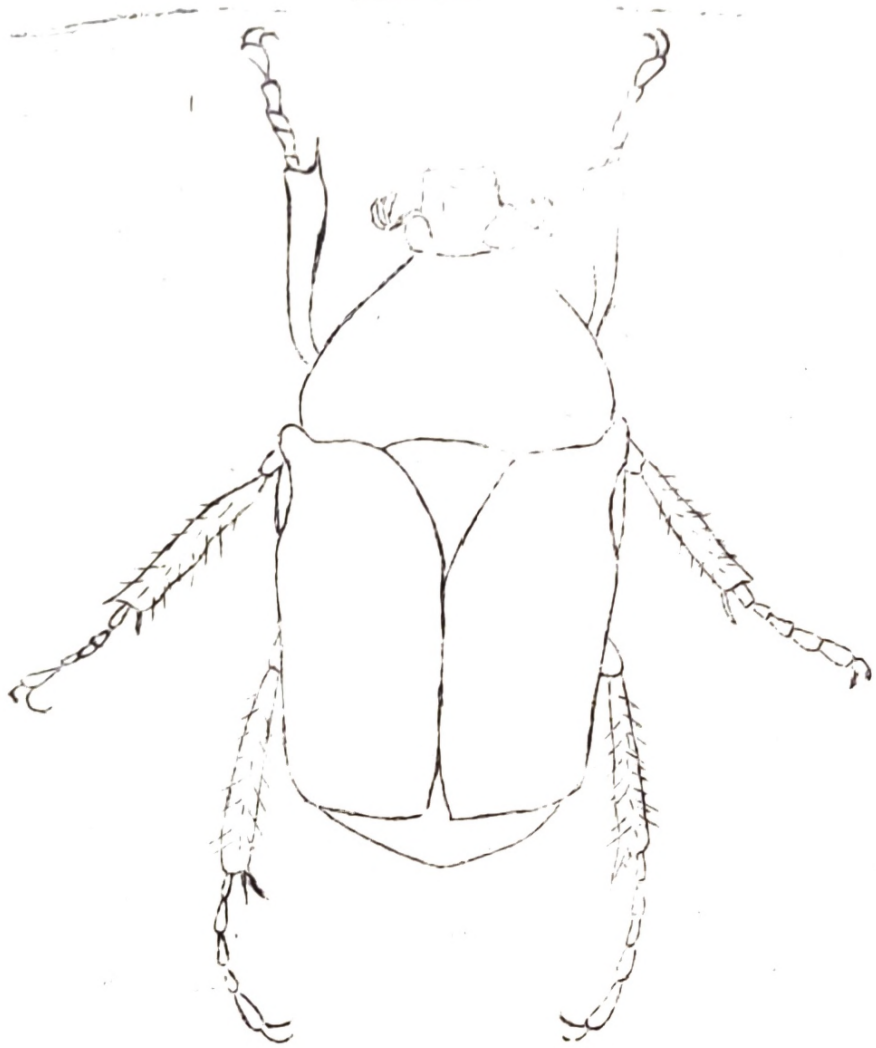

Fig. 52

Fig. 53

PLATE XVIII

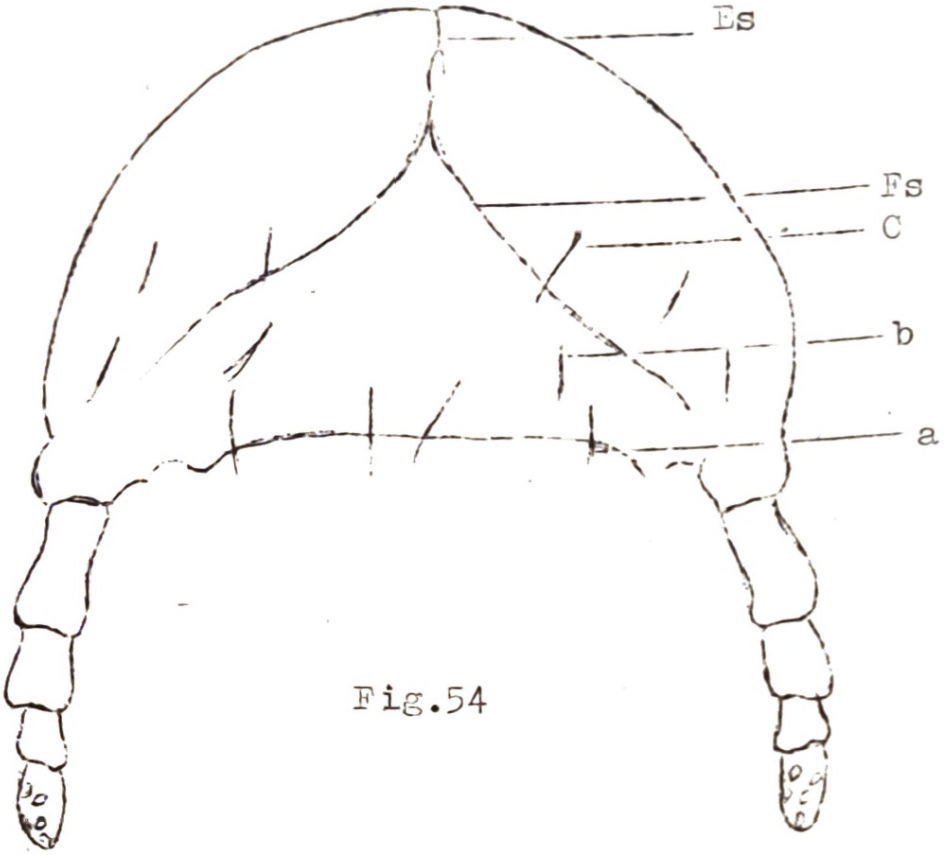

Fig.54

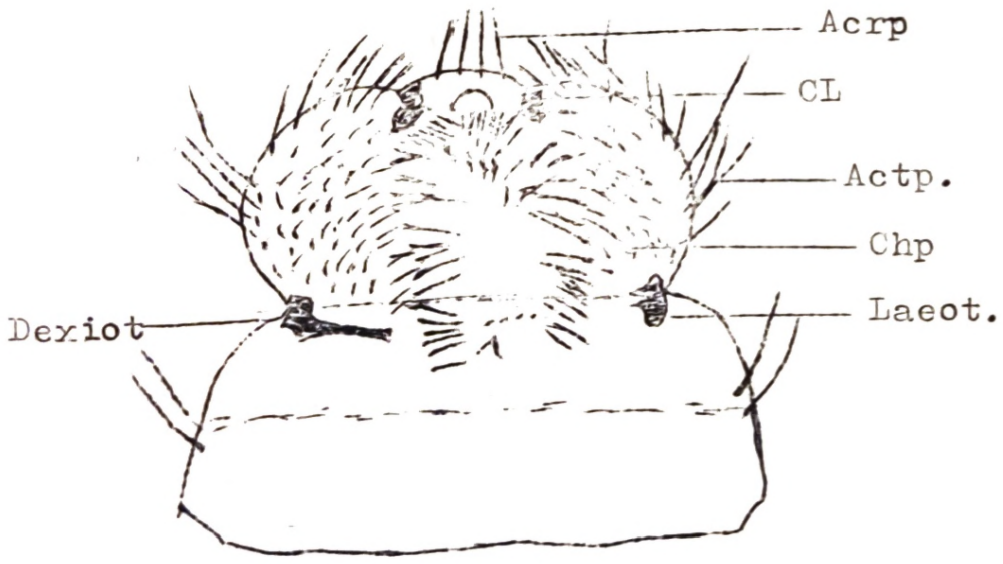

Fig.55

PLATE XIX

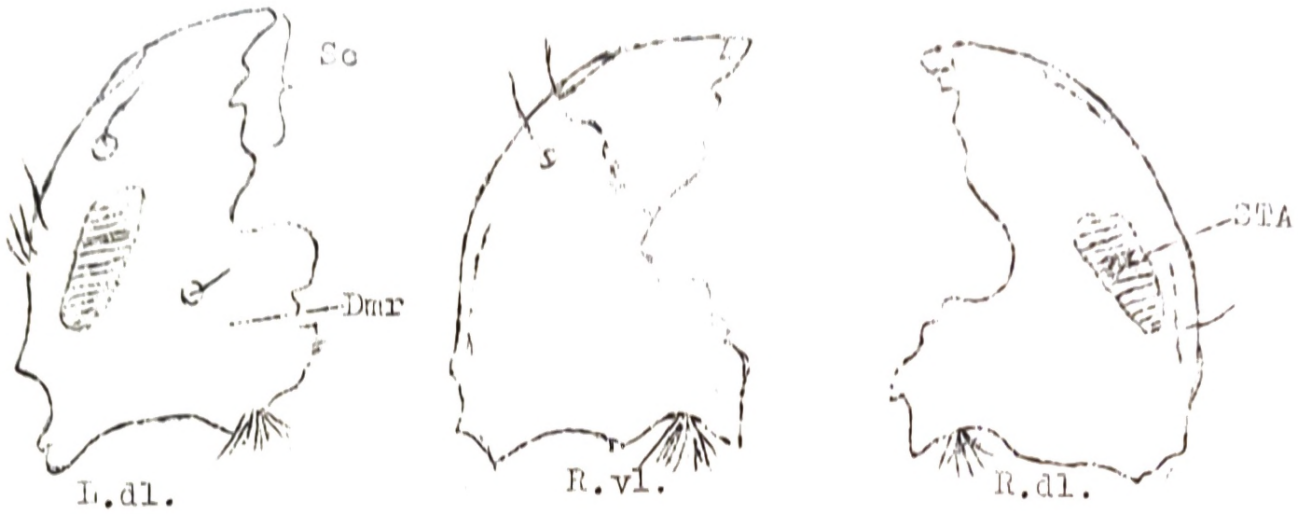

Fig.56

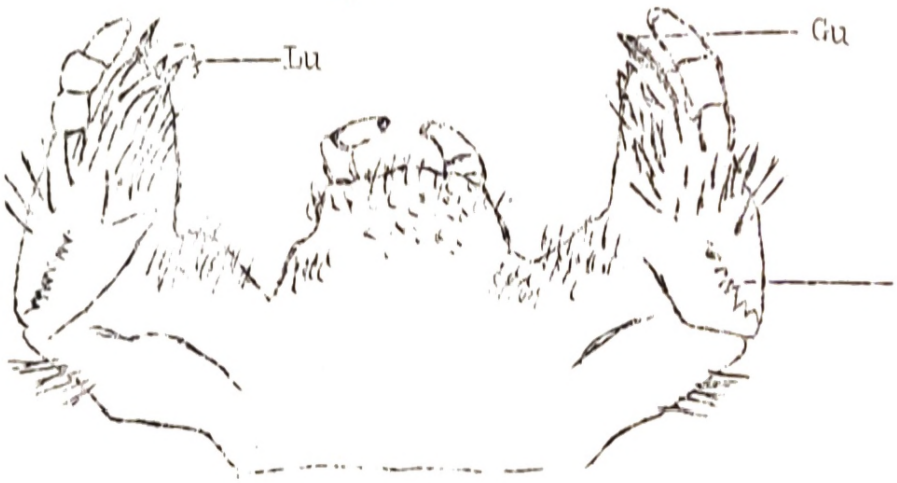

Fig.57

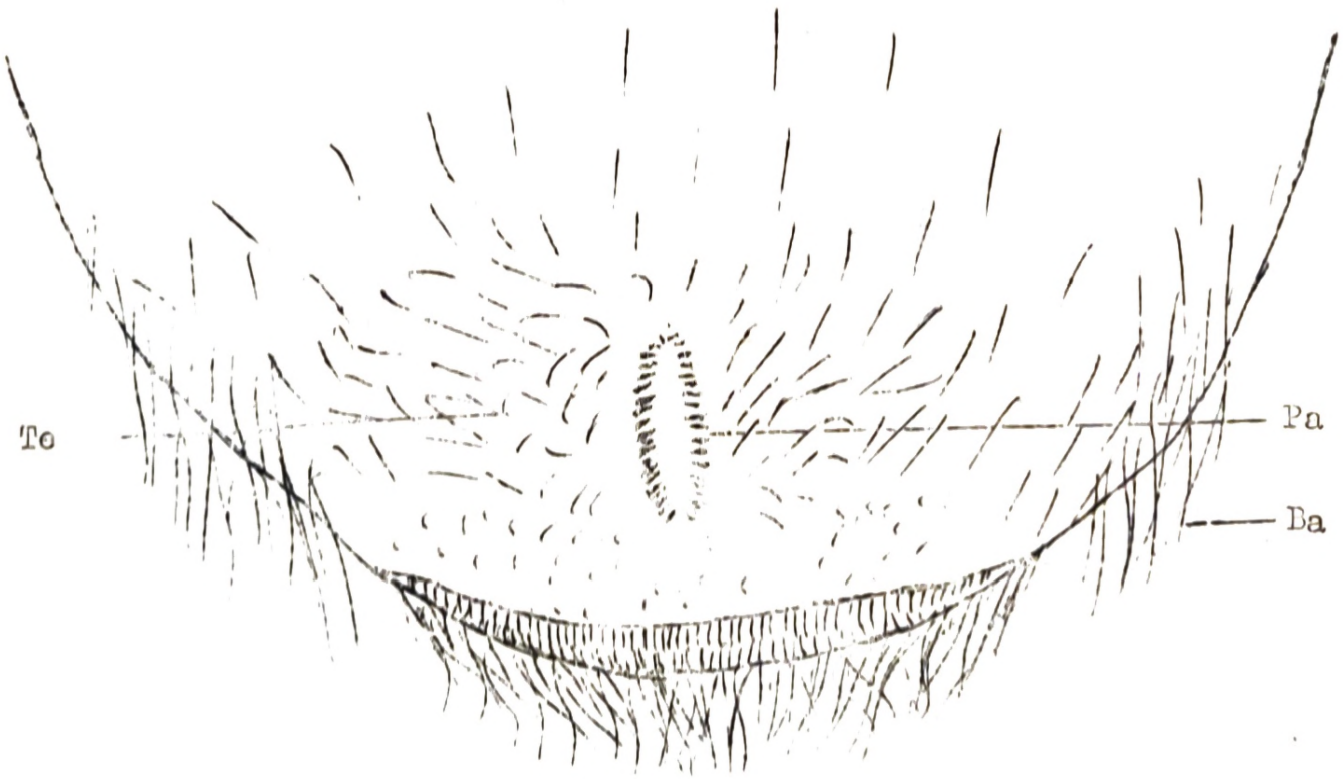

Fig.58

PLATE: XX

Fig. 59

Fig. 60

Fig. 61

Fig. 62

Fig. 63

plegmata and proplegmata absent; laeotorna and dexiotorna present.

Mandible (Fig. 56): Scissorial part of right mandible composed of four distinct teeth; Dorsomolar region bearing single seta, scrobis with four to five setae, oval patch of stridulatory area present on ventral side of each mandible.

Maxilla (Fig. 57): Cardo sub-quadrate. Galea and lacinia fused. Galea with stout single uncus and lacinia bearing two unequal unci. Stipes bearing five to six stridulatory teeth.

Haster (Fig. 58): Septula elongate. Each palidium composed of 22-24 short, stout, flat, pali meeting anteriorly; tegellum with numerous long pointed setae. Barbula furnished with numerous long setae. Upper and lower anal slit furnished with setae in a single transverse line on its posterior side. Anal slit transverse.

6. Dynastinae:

Adult (Fig. 68): Stout bodied insects, 10-70 mm long and mainly black, dark-red, brown or yellowish-brown in colour. Males frequently bear horns or tubercles on the head or thorax or both, majority of the species being nocturnal or crepuscular in habit.

The adults are characterised as follows: Clypeus is generally small and the eyes less prominent. Mandibles well developed. Maxillae are generally furnished with several sharp strong teeth and closely fringed with stiff hairs. The mentum and ligula are fused together, and the labrum, small, membranus and concealed. The front coxae are more deeply embeded in thorax, broad and transverse, all coxae are continuous in the middle. Claws are always simple symmetrical and immovable.

They are mostly tropical and exhibit the most diverse food habits. Larvae of several species attack the roots of sugarcane and rice. Rhinoceros beetles are well known pests of pa[illegible].

Larva (Fig. 69): Dynastid larvae are distinguished by the following characters:

Mandibles with a ventral oval stridulatory structure consisting of numerous transverse granular ridges, usually much wider posteriorly. Maxilla with well developed stridulatory teeth which are truncate. Lacinia of maxilla with an oblique or transverse row of preterminal unci which are more or less fused together at their bases. Haptomerum of epipharynx with a raised, bilobed or entire ridge or a tooth-like process distinct, zygum prominent; heli absent. Plegmatia and proplegmatia absent, ocelli usually present. Raster usually without palidia. Anal slit transverse and curved.

Oryctes rhinoceros Linn.

Larvae were collected from manure pits at Bangalore, and reared in the laboratory up to adults to get their identity. Larvae of this species may be characterised as follows:

Cranium (Fig. 70): Dark-brown, reticulate and covered with numerous prominent pits. Anterior region of frons bare, exterior angle with three setae on each side. Dorso epicranial setae 5-6 in number on each side of epicranium clypeo-frontal suture well marked, frontal and epicranial suture distinct.

PLATE: XXI

Fig. 64 Fig. 65 ig. 67 Fig. 66

PLATE: XXII

Fig. 68

Fig. 69

Epipharynx (Fig. 71): Apical margin indented slightly in the region of epipharynx. Haptomerum consist of fused epizygum-zygum, anterior process not noticed. Plegmata, proplegmata absent. Acanthoparia bearing 10 course setae. Chaetoparia large with many coarse setae. Pedium longer than wide. Laeotorma well developed with rounded pternotormal process. Dexiotorma straight.

Mandibles (Fig. 72): As long as head, para scissorial area with two prominent teeth. Manducatorial portion of the right mandible with oblique molar which prominently projecting posteriorly. Heel large and the grinding surface flat. Left molar part anteriorly prominent and posteriorly retracted. Scrobis bearing 5-6 minute setae and 2-3 punctures; Dorsomolar region of right mandible be set with 12-13 setae. A circular patch of 5-6 coarse setae located near stridulatory area of each mandible.

Maxilla (Fig. 73): Maxillary lobes fused into a single fleshy and setose structure. Galea with a single curved, prominent uncus around which it provides with many stormy setae. Lacinia with three strong conical unci and numerous stiff setae stipes furnished with a row of 9-10 truncate stridulatory teeth and a blunt tubercle at the distal end.

Raster (Fig. 74): Consisting of a teges and Carmus. Teges made up of a broad patch of about 65-80 hamate setae. Anal slit transverse. Dorsal anal slit furnished with 30-35 short straight setae interspersed with very few long fine setae. Lower anal lobe covered with about 50-60 short setae.

7. Melolonthinae:

Adult (Fig. 75): [illegible] family is world-wide in distribution and are [illegible] to agricultural crops. Adult-beetles feed on foliage of trees, shrubs, flowers or fruits. Beetles of 5 to 40 mm long and usually of reddish-brown colour rarely black or metallic.

The adults are characterised as follows: [illegible]. Head with labrum sclerotized and visible externally, rarely fused with the clypeus, claws equal fixed with or without a tooth beneath; head and prothorax without horn or tubercle.

Larva (Fig. 6): The larvae are subterrenean and feed on roots of different plants and organic matter. The larvae are characterised by Mandibles without ventral stridulatory area. Scissorial area of mandible with a distal blade-like portion which is separated from a proximal tooth by the scissorial notch. Galea and lacinia of maxilla fused proximally, separated distally. Antenna four segmented, last antennal segment with a single elyptical dorsal sensory spot. Anal opening usually angulate or Y shaped. Lower anal lip usually with a sagittal cleft or groove. Legs well developed four segmented.

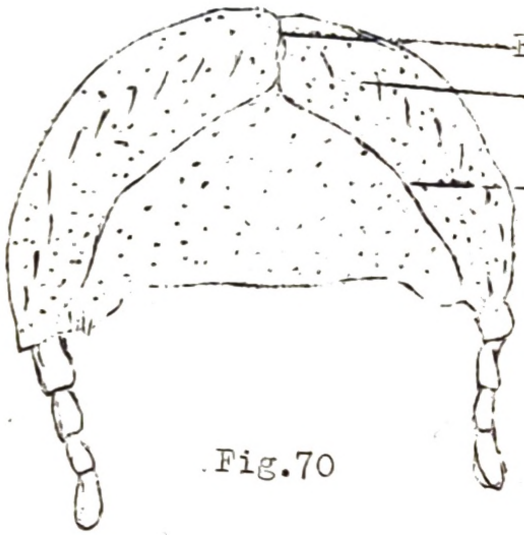

Fig.70

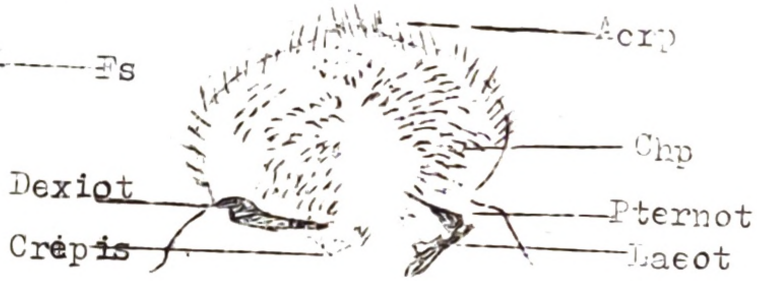

Fig.71

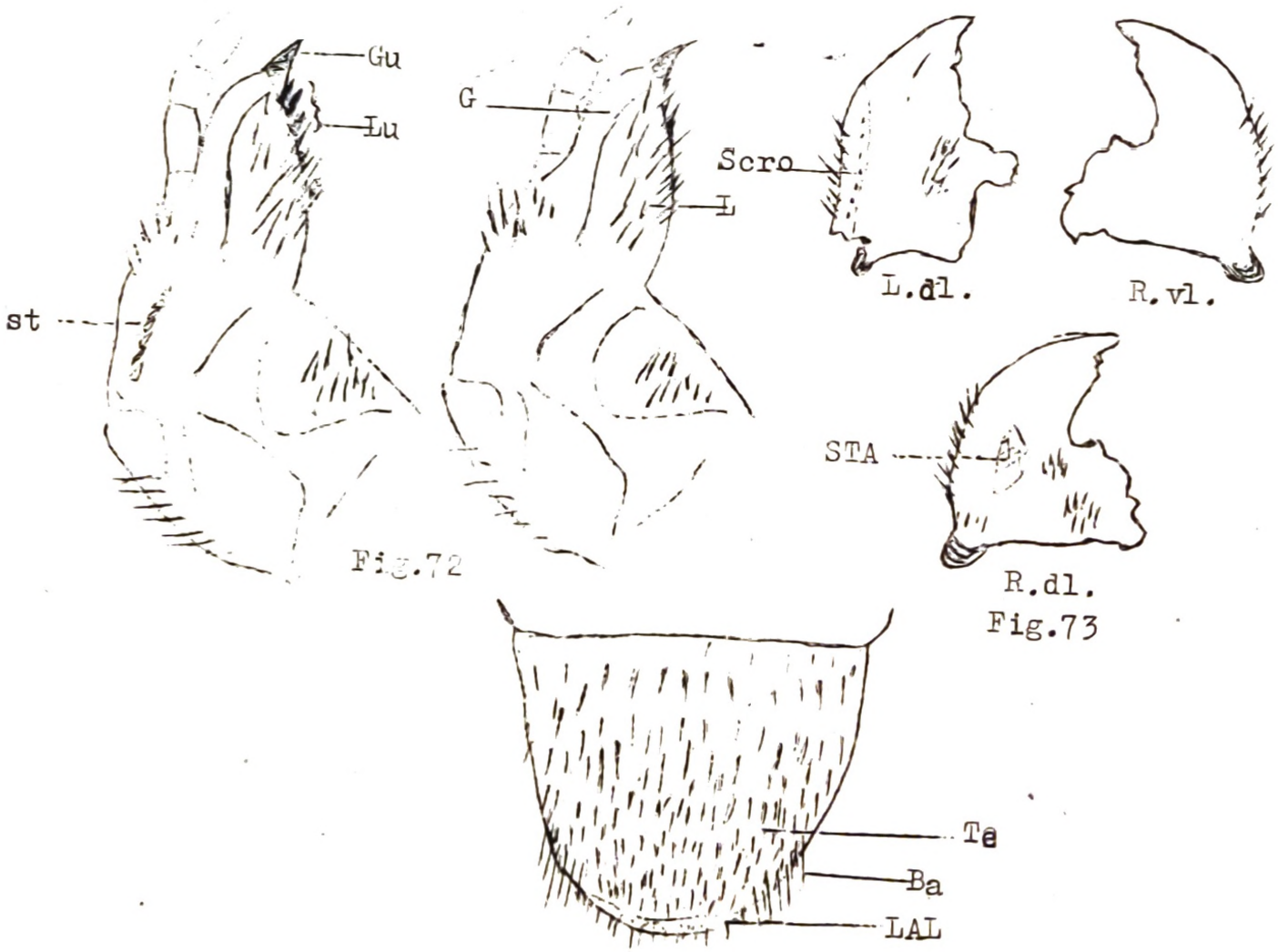

Fig.72

Fig.73

Fig.74

PLATE: XXIV

Fig. 75

Fig. 76

KEY TO THE TRIBES OF MELOLONTHINAE ENCOUNTERED IN THE PRESENT STUDY BASED ON ADULT CHARACTERS

1. Tibia with one spur or [illegible] and meso-tarsal claws chelate and [illegible]; Onychium not present .....HOPLIINI Dalla tore

Meso and meta-tibiae with two spurs, tarsal claws equal, some times chelate; Onychium present ... 2

2. Anterior coxae conical, prominent; Labrum fused with under surface of clypeus; claws not chelate; terminal and hind tibial spurs sets one on each side of the basal tarsal segment .... SERICINI Dall tore

Anterior coxae transverse, not very prominent, not deeply set; Labrum seprate from clypeus; both the hind tibial spurs set on one side of the basal tarsal segment ..... MELOLONTHINI REITTER

--:--

KEY TO TRIBES OF THE SUB-FAMILY MELOLONTHINAE EN-COUNTERED IN THE PRESENT STUDY BASED ON LARVAL CHARACTERS

1. Raster with longitudinal or transverse palidia or with palidia absent 2

Raster with a curved transverse, comb-like palidium. Haptomerum of epipharynx with 2-3 heli ..... tribe SERICINI

2. Haptomerum of epipharynx with a single helus, raster without palidia ..... tribe HOPLIINI

Haptomerum of epipharynx with more than 3 heli Raster with or without palidia .tribe MELOLONTHINI

-:-

Tribe: Sericini:

Adult beetles rather small, ovate, oblong, robust, brown often covered with silky iridescent pubescence; body widened posteriorly, labrum indistinct; connate with the under-surface of clypeus; Elytra shallowly striate; Metacoxae flat, dialated as wide as any two sternites together, metafumera slender. Terminal hind tibial spurs set one on each side of the basal tarsal segment. The beetles are nocturnal in habit, feed on Acacia spp. Rosa spp., Ajaridcta indica Ages etc. They are highly attracted to light. Unlike other melolonthids these have two generations per year. A female lays about forty to sixty eggs in groups of 10 to 20.

The life cycle is completed in 3 to 4 months (in few species).

Larva: The larvae feed on organic matter initially and in the later stages they feed exclusively on live roots. Larvae of this tribe are small to medium size and characterised as follows. Head with few setae; anterior frontal setae absent, posterior frontal setae and setae in anterior angle of frons consisting of a single seta on each side. Eye spots usually present, black pigmented. Labrum symmetrical, distally trilobed. Epipharynx with a well-developed epizygum. Haptomerum with 3 or 4 heli. Plegmatia present, proplegmatia absent. Maxilla with peg like stridulatory teeth. Cardo and articulating membrane of maxilla with groups of dark granules. Thoracic spiracles much larger than abdomen spiracles. Raster with a single, transverse slightly curved, comb-like row of flattened pali just anterior to the ventral anal

lobes. Anal slit 'Y' shaped. Dorsal anal lobe much smaller than ventral anal lobe. Anal lobe densly setose.

Autoserica nathani

Grubs were collected from Varanasi, Dharwad, Nandi Hills and Bangalore during October 1978. Larvae obtained from Varanasi (U.P.) were reared to adults. Adults of this species are attracted to the light trap throughout the year. Biology of this species has been studied in the laboratory. Unlike other melolorthids, this has two generation per year. A female lays about 40-60 eggs and the life cycle is completed in 3-4 months. The larvae feed on roots. Larvae of this species may be characterised as follows:

Cranium (Fig. 77): Smooth, light brown; anterior frontal setae absent; a single post frontal seta and dorsoepicranial seta present on each side; a group of 7-8 small and 4-5 long setae are present near the base of the antenal ring.

Epipharynx (Fig. 78): Trilobed with distinct zygum and epizygum; heli stout, 3 in number in a transverse row. Acroparia bears 5-7 long spine-like setae, proplegmata absent; plegmata 10-15 in number on each side, haptoroma with epitormal and apotormal process. Dexiotorma well developed. Crepis thin.

Mandibles (Fig. 79): Scissorial part with a wavy cutting edge; 7-8 setae present on the dorsomolar part of right mandible and 4-5 on that of the left mandible. Ventral side of each mandible furnished with 6-7 punctures and 4-5 setae are present on scissorial part.

PLATE XXV

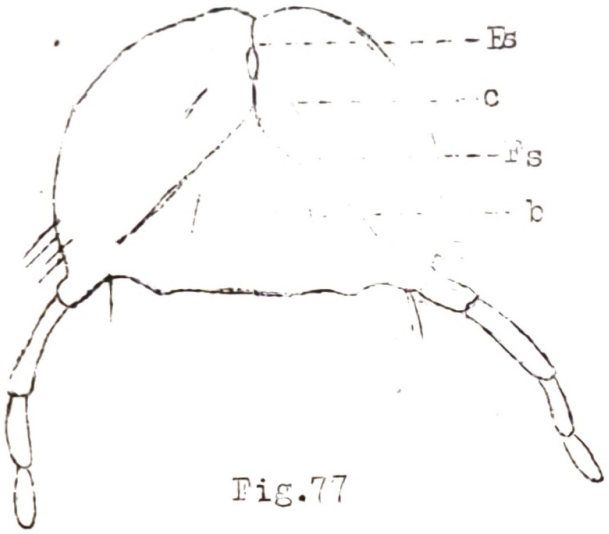

Fig.77

Fig.78

PLATE XXVI

Fig.79

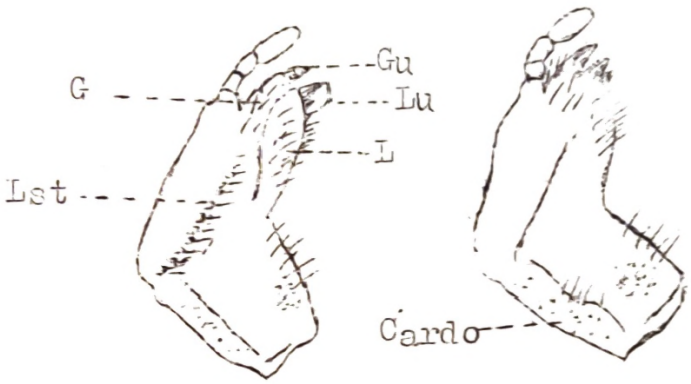

Fig.80

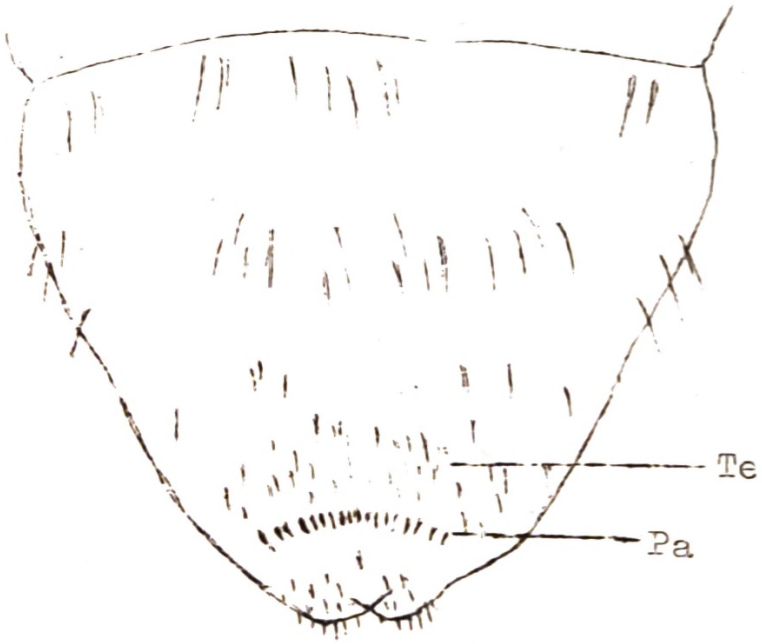

Fig.81

Maxilla (Fig. 80): Cardo subrectangular with 5-6 granules; maxillary articulating membrane with a patch of 20-25 granules; maxillary stridulatory area consists of 18-20 teeth, proximal teeth are relatively small and blunt, while distal teeth are sharp.

Raster (Fig. 81): With a single transverse slightly curved comb-like palidium, consisting of 16-20 short flattened pali, just anterior to the ventral anal lobes. Each tegillum consists of 20-25 short pointed hamate setae.

Autoserica attratula Br.

Adults are small, oval, strongly convex with golden blueish-green shades. Clypeus small and irregularly punctate, pronotum smooth elytra finely punctate and parallel with striations. Adults which were attracted to the light trap were collected at Bangalore during June 1980. Larvae were reared in the laboratory from the adults by providing live roots. Larvae may be characterised as follows:

Cranium (Fig. 90): Smooth, yellowish-brown, anterior marginal region of frons bare, a single post frontal seta and dorsoepicranial seta present on each side. A group of small and long setae are present near the base of the antennal ring.

Epipharynx (Fig. 91): Symmetrical and trilobed, zygum and epizygum distinct. Plegmatia present each plegmatium consists of 10-12 plegmata. Proplegmatia absent. Pedium oval, haptomerum with three stout heli and two macrosensilla laeotorma short, dexiotorma rod-like crepis circular.

Mandibles (Fig. 92): Light-brown in colour. Scissorial area with slightly curved cutting edge. Six to seven granular spots present on ventral aspect of each mandible. Dorsomolar part of right and left mandible furnished with 10-11 and nine setae, respectively. Scrobis provided with five to six setae.

Maxilla (Fig. 93): Cardo provided with seven to eight dark granules. Maxillary articulating membrane with 14-15 granules; stipes consists of 22-24 peg-like stridulatory teeth.

Raster:(Fig. 94): Consists of single curved palidium with 12-15 sparsely set rather long pali. Each tegellum be set with 10-15 hamate setae long fine setae cover nearly entire area from palidium to cephalic margin of last abdominal segment. Anal lobe setose.

Kalodera Sp. I

Larvae collected in cardamom estates of Coorg district in the month of September 1978 in the organic matter. Larvae were reared to adults in lab and adults formed in the month of January 1979. Larvae of this species may be characterised as follows:

Cranium (Fig. 106): Surface smooth, light yellowish-brown, anterior frontal setae absent; a single dorsoepicranial setae present on each side.

Epipharynx (Fig. 107): Acroparia consists of 9-10 long spine-like setae; Soli stout, 2 in number, transversely arranged; plegmata short, plegmatium

PLATE: XXVII

Fig. 82

Fig. 83

Fig. 84

Fig. 85

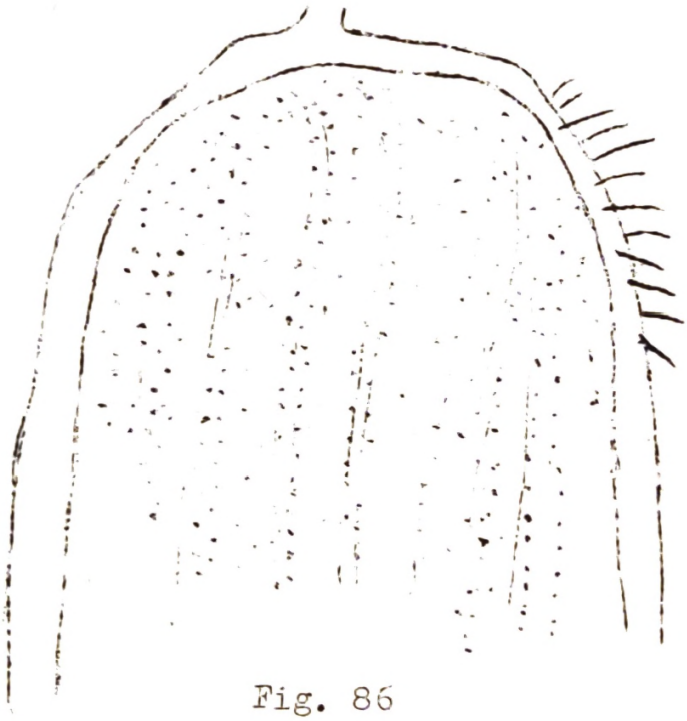

Fig. 86

Fig. 89

Fig. 87

Fig. 88

PLATE XXVIII

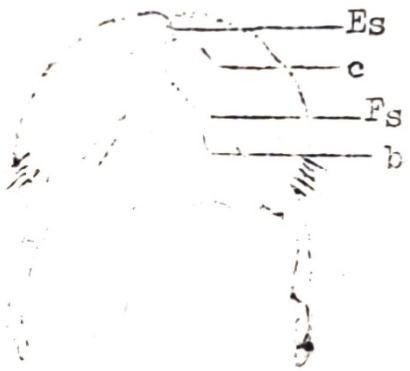

Fig.90

Fig.91

Fig.92

PLATE XXIX

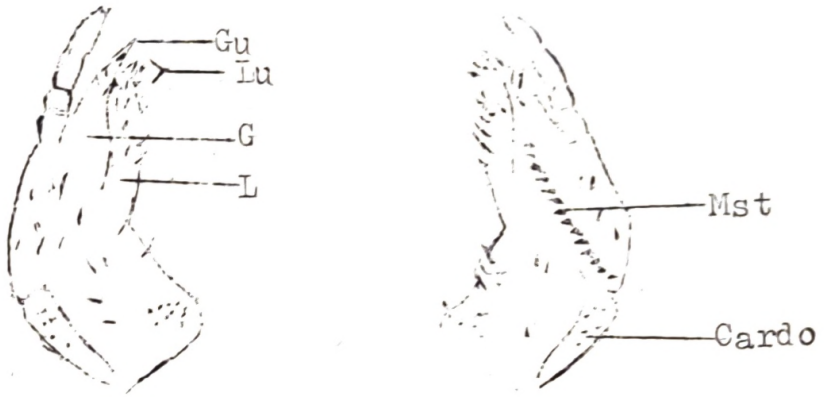

Fig.93

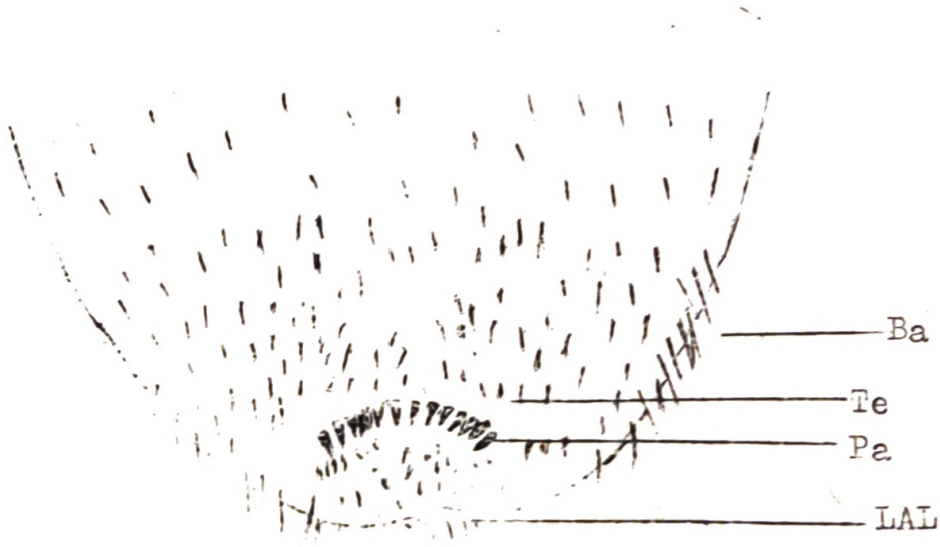

Fig.94

PLATE: XXX

Fig. 95

Fig. 96

Fig. 97

Fig. 98

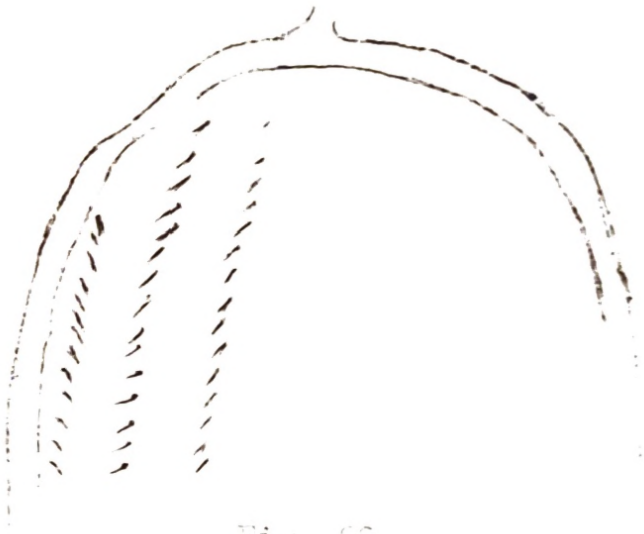

Fig. 99

Fig. 100

Fig. 10

consists of 10-12 plegmata on each side. Proplegmata absent. Zygum and epizygum distinct, and continuous; laeotorma, pternotorma distinct, epitorma, apotorma indistinct, dexiotorma long and slender.

Mandibles (Fig. 109): Scissorial part has almost straight cutting edge with deep notch. Each mandible possess 3 puncture on the scissorial part; scrobis, moderately long with a single setae.

Maxilla (Fig. 108): Cardo, rectangular, furnished with 9-10 granules; maxillary articulating membrane with a patch of 15-20 granules; maxillary stridulatory teeth consists of 20-25 teeth; distal teeth arranged closely.

Raster (Fig. 110): With single transverse slightly curved comb-like palidium consists of 24-26 pali, anterior to ventral anal lobe. Tegillum consists of short pointed hamate setae.

Maladera spp. II

Adults were collected during May 1980 in Indian Institute of Horticultural Research, Hessarghatta, adults were feeding actively on Guava, Sapota. Larvae reared in the laboratory from adults and are characterised as follows:

Cranium (Fig. 111): Smooth, light-brown, anterior frontal setae absent, a single post frontal seta present on each side. Antenal ring support provided with 3-4 setae. Frontal suture and epicranial suture distinct.

Epipharynx (Fig. 112); Trilobed, with distinct zygum and epizygum. Heli stout 3 in number in a transverse row. Acroparia bears 6-8 long setae. Proplegmata

absent. Plegmata 8-10 in number on each side. Laeotorma with apotormal process. Dexiotorma dark, crepis thin.

Mandibles: (Fig. 114): Scissorial part with a wavy cutting edge; 4-6 setae present on the dorsomolar part of right mandible. Scrobis elongate, provided with 1-3 setae.

Maxilla (Fig. 113): Cardo rectangular with 5-6 granules. Maxillary articulating membrane with a patch of granules maxillary stridulatory area consists of 18-20 teeth, proximal teeth relatively small and blunt, while distal teeth are sharp.

Raster (Fig. 115): With a single transverse curved comb-like palidium, consisting of 16-18 pali, just anterior to the ventral anal lobes, each tegillum consists of 14-16 short, pointed cremate setae.

Autoserica sp.

Larvae collected from coffee and cardamom estates of Coorg district in the month of September 1979. Grubs were found damaging the seedlings severely. Larvae of this species may be characterised as follows:

Cranium (Fig. 103): Surface smooth, light brown in colour, anterior frontal suture and epicranial suture, distinct, epicranium possess two dorsoepicranial setae, one on each side.

Epipharynx (Fig. 104): Acroparia is distinct with 4-5 long spine like setae; heli 2 in number,

PLATE XXXI

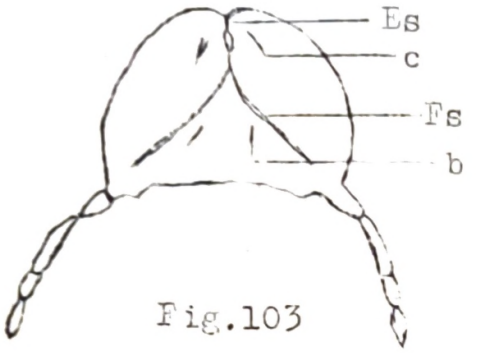

Fig.103

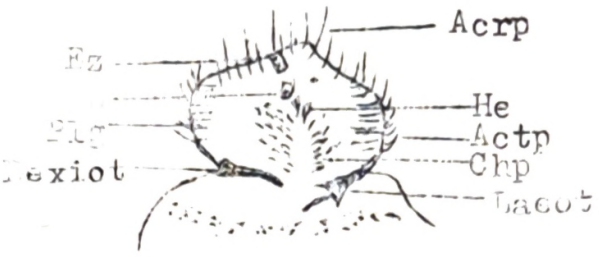

Fig.104

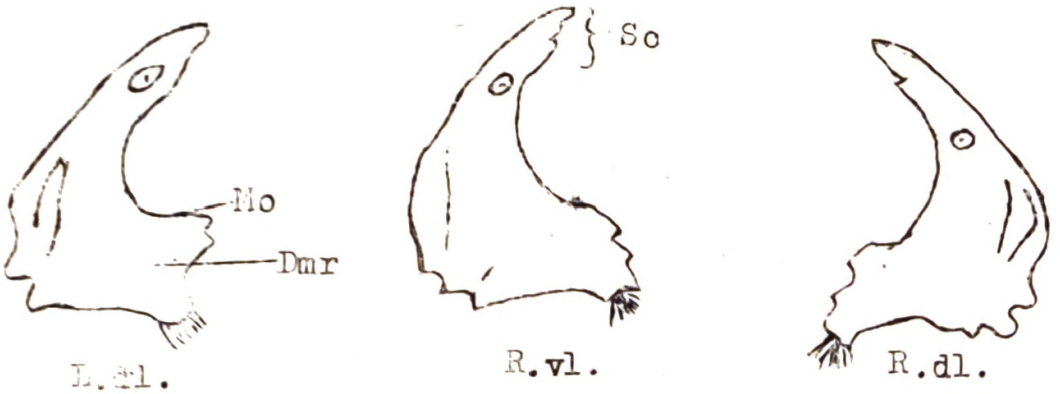

Fig.105

PLATE XXIII

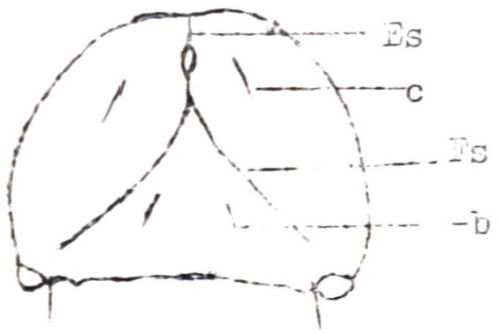

Fig.106

Fig.107

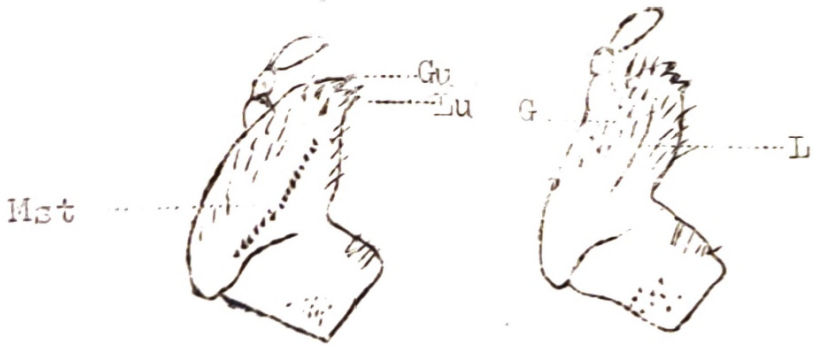

Fig.108

PLATE XXXIII

Fig.109

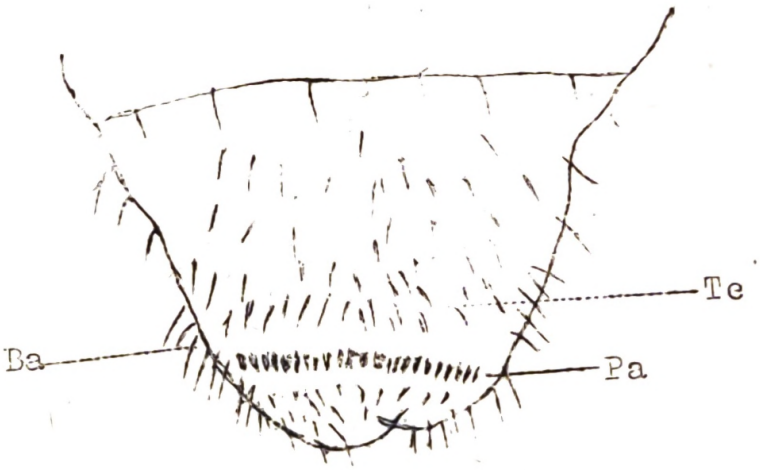

Fig.110

PLATE XXXIV

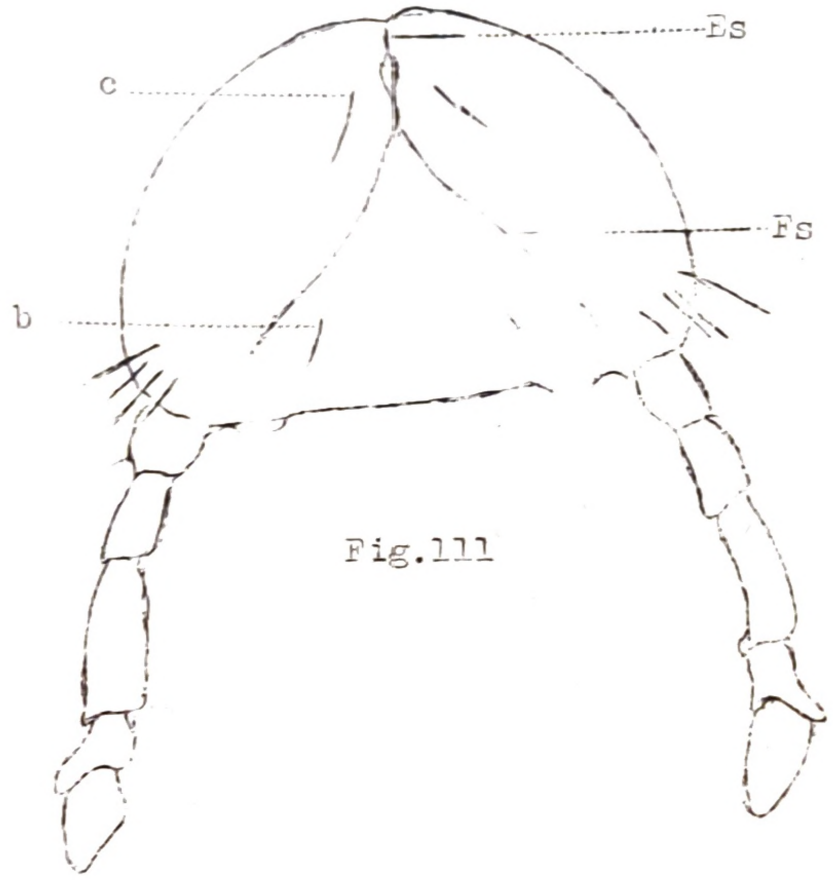

Fig.111

Fig.112

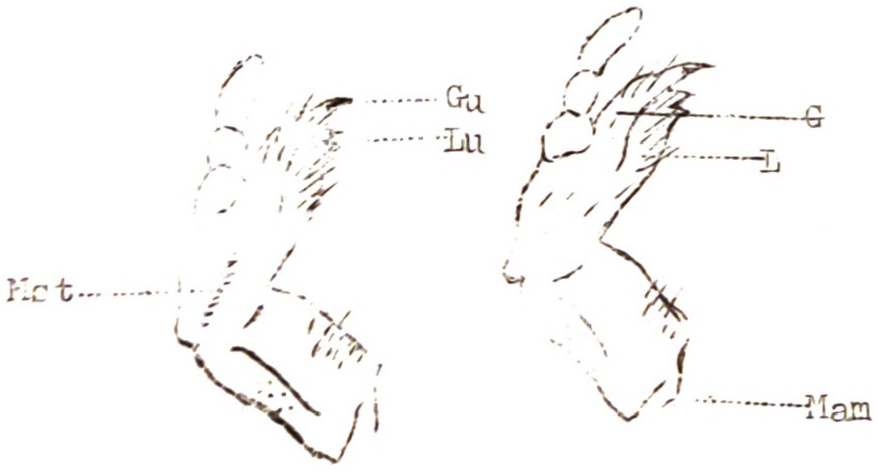

Fig.113

transversly arranged. Plegmata 8-10 on each side, proplegmota absent. Zygum and epizygum distinct and continuous forming a Y shaped structure. Laeotorma, pternotorma present, dexiotorma long and slender.

Mandibles (Fig. 105): Scissorial part has straight cutting edge, the latter posterior limited with deep notch; dorsomolar setae absent. Each mandible consists of 4 punctures on the scissorial part. Scrobis with a long single setae.

Maxilla: Cardo rectangular furnished with 8-9 granules. Maxillary articulating membrane with a patch of 10-12 granules.

Tribe: HOPLIINI

Genus Hoplia Illiger: Small, oblong, rather robust, sub-depressed beetles; antennal club three segmented; tibiae with one spur or none; tarsi without onychium; claws of pro and mesotarsi unequal in size, the external one larger, bifid at apex; metatarsi and some times mesotarsi with only one claw.

Ex: Hoplia viridissima Brenske: (determined by S.K. Chaterjee, Z.S.I.) Distribution - West Bengal.

Adult characters: Oblong, robust, pronotum and elytra rather densely covered with flattened yellowish green, oval scales; pygidium, abdominal stermites and ventral surface of thorax covered with silvery scale; ventral side of head and mouth parts reddish brown; antennal club prominent; legs reddish brown covered with white, elongate hairs and scales; fore tibia

dentate. Length 4.5-5 mm. Adults may be collected from flowers during day time in the months of May and June at higher altitudes of West Bengal. Larva not reared to adult.

Tribe Melolonthini

Body usually cylindrical, Labrum strong separate from clypeus; anterior coxae transverse, but not deeply set in the thorax; both terminal hind tibial spurs set on one side of the basal tarsal segment. These are popularly known as "Chafers", "May-beetles" or "White grubs". Adults nocturnal in habit, emerge after dusk, active whole night on clear days, get back to the soil before dawn. Adults are attracted to preferred hosts like neem, Ajadirecta indica Apes, Casia fistula. Acasia arabica, Moringa oleracea etc. Adults of Schygonycha are commonly found on tammerind trees and of the genus Apogonia are commonly attracted to light they can be collected from Casurina and banian trees. The adults of Leucopholis have not been so far known to feed on any plant their emergence also occurs in the early evening before dusk. The adults normally do not migrate beyond 100 metres from the place of emergence. Although, adults of the members of the genus Holotrichia are known to attract to light sources, but light traps do not help in capturing them. They come from distance towards light source but settle on the ground as they come within 5-7 meters from the light source. Copulation takes place immediately after emergence and lasts 5 to 10 minutes on shrubs or trees. They seems to be strongly guided by the sex pheromones in their distribution, as they tend to congregate for egg laying in

localised patches. The larvae are phytophagus and are some of the worst pests of cultivated crops. The major destructive section of white grubs belongs to this tribe. Some are strongly attracted to light.

Larval characters - Type - Holotrichia serrata F.

A large number of species under this tribe are of great economic importance in this country. All the species undergo one generation in a year. Their major activity will be during June to November, larvae have been recorded to feed on almost every plant root under all situations except in standing water. They have been collected from upper Simla hills at 3000 M altitude feeding on potato to coastal Kerala on coconut and tuber crops. No state and union teritory of India is completely free from the ravages of the grubs. Their increase damage to cultivated crops have been reported since two decades they are of major consequence to Sugarcane, Groundnut, Sorghum, Maize, Tobacco, Coffee, Coconut, Arecanut, Tuber crops, Vegetables etc., nearly one hundred species under the genus Holotrichia alone have been described from Indian Sub-continent. The member of the genus Leucopholus are recorded causing damage to Arecanut, Coconut, Sugarcane and tuber crops in the West Coast, the members of the genus Schyzonycha although are of common occurrence, the larvae have not been encountered causing appreciable damage to cultivated crops in this country. The Apogonia sp. cause damage to prunes and pears in their adults stage after emergence, but their larvae have not been found causing much damage. The members of the genera Neodontochnema and Hoplosternus have not been encountered during the course of this study.

KEY TO THE GENERA OF THE TRIBE MELOLONTHINI BASED ON ADULT CHARACTERS

1. Antenna 10 segmented 2

   Antenna 9 segmented ..... NEODONTOCNEMA Arrow

2. Mesosternal process present between coxae; antenal club of female 5 and that of male 7 segmented .. .. HOPLOSTERNUS Guer.

   Mesosternal process absent; antennal club with 3 segments 3

3. Body covered with scales; elytra without costae; Last segment of maxillary palpi with a flattened dorsal depression ..... LEUCOPHOLIS Blanch.

   Body either bare or hairy but never with scales; Elytra with or without costae; Last segment of maxillary palpi with or without dorsal depression 4

4. Clypeus extending at least up to the middle of the compound eyes dividing the compound eye in the middle; hind tibia without a distinct ridge ..... APOGONIA Kirby.

   Clypeus not extending to the middle of compound eye; hind tibia with a distinct ridge bearing spines in semicircle 5

5. Clypeal carina present; elytral costae absent; claws bifid towards tip outer being smaller than inner ..... SCHYZONYCHA Blanch.

Clypeal carina absent; elytral costae present; claws bifid towards the middle, outer being bigger than the inner ..... HOLOTRICHIA Hope.

Nomenclature of the genus Holotrichia Hope

There is a good deal of confusion about the identity and nomenclature of the genus Holotrichia in this country. Two names are commonly used for this genus in India, Lachnosterna Hope and Holotrichia Hope (Stebbing, 1899; Fletcher, 1921; Lefroy, 1900: Beeson, 1941; Gupta and Avasthy, 1957; Haq, 1962; Devid and Kalra, 1966). In recent years, the specialists of the British Museum, London identified the genus as Phyllophaga (Phyllophaga serrata F.). The two genera Holotrichia and Lachnosterna were described by Hope (1837) on successive pages of the Coleopterist's Manual (Part I, page 99 and 100).

Holotrichia was treated as Synonym of Lachnosterna in the Munich Catalogue of 1869, but the Dalla Torre catalogue of 1912-13 revived Holotrichia for Old world species and employed Lachnosterna for those of New World. Arrow (1948) concludes that 'Lachnosterna Hope, so long in general use both in Europe and America is certainly to be preferred and the appearance of the name Holotrichia on the preceding page to Lachnosterna is of no real priority'.

The name Phyllophaga was proposed by Harris in 1826. Leconte (1855), after considering the history of these names, was convinced that for the sake of purity in nomenclature, the name Lachnosterna should be

adopted and that Phyllophaga and Ancylonycha should be rejected since they were not supported by valid description to indicate the limits of the genus. Lacordaire (1856) was in accord with this view and pointed out that the name Phyllophaga Harris was a nomen nudum and should therefore be rejected.

The name 'Phyllophaga was revived by Glasogow (1916) on the ground that its validity was fully established by its publication in connection with a series of valid specific names'. His argument for the change was supported by the International Code (Hayes, 1925).

Saylor (1937) and Arrow (1948) regarded both old and new world species as congeneric. If they are followed, the valid name of the genus is Phyllophaga Harris as this name is available according to the International Code of Zoological nomenclature. Fennah (1972) however stated that Lachnosterna Hope is synonym of Phyllophaga and not Holotrichia. Frey (1971) has kept the old World species separate and retained Holotrichia Hope for this, and the name Phyllophaga being restricted to those of the New World. In the latest book of Entomological works from Museum G. Frey, he has included 96 species under the genus Holotrichia under 5 groups from the Indian Sub-continent, twelve species of which are included in this report.

To avoid further confusion, the genus Holotrichia Hope, has been retained in the present work. Both by its long usage in the Indian sub-continent and also priority given by Hope in the Coleopteristis Manual

(Part 1, Page 99) all the names under the genus Lachnostera Hope is substituted by the genus Holotrichia Hope as there is no clear cut description to seprate these two genera. According to Arrow (1948) the following genera are Synonym with the genus Holotrichia Hope, Lachnosterna Hope, Brahyna Blanch, Hoplochelus Blanch., Anomalochela Mose Amylonycha Blanch and Cnemarchis Saylor.

GENUS HOLOTRICHIA HOPE

1. Underside of thorax with long, thick to very thick hairs 2

   Underside of thorax bare or with very scanty seate 4

2. Pronotum and elytra with hairs or bristles. GROUP I

   Pronotum and elytra bare 3

3. Elytra and pronotum dull ..... GROUP II

   Elytra shining, pronotum may or may not be shining ..... GROUP III

4. Underside of thorax bare; forehead with Keel ..... GROUP IV

   Underside of thorax with spars, Scattered minute hairs, forehead without Keel ..... GROUP V

GROUP I

1. Length less than 15 mm 2

   Length usually 17 mm 4

2. Upper side dark brown 3

   Upper side pale brown: Clypeus rectangular, fairly long, front edge very much bent up; Pronotum and elytra with scattered punctations and with scattered thick hairs, length 11 mm distribution Kulu, N. India .....batillina Bat. (Lachnosterna)

3. Clypeus pointed, finely punctate, front margin crenate slightly curved inwards, corners broadly rounded, hairs thicker on prothorax and elytra, slightly longer, shining, length 12 mm distribution Sikkim .....hirsuta Mose.

   Clypeus broad thickly punctate, margin curved in, with minute dentation. Upper surface flat, hairs thicker and longer on prothorax than on elytra. Prothorax thick, umbolicle pointed with smooth transverse middle line. Elytra without ridges length 13 mm distribution Ceylon, Male genitalia fig. 116..... kandulawai Frey.

4. Hairs slightly thick and much scattered on prothorax, shiny with middle line and two shiny flecks; clypeus slightly curved, length 17 mm distribution West Bengal ..... plagiata Br.

   Prothorax without shiny flecks 5

5. Elytra tomentose setae slightly glossy 6

   Elytra shiny 11

6. Prothorax very long with scattered hairs, head thickly punctated 7

   Prothorax short 10

7. Prothorax with long and scattered hairs, head thickly punctated 8

   Prothorax thickly punctated, umbelic pointed, clypeus edge trimmed, elytra parallel, brown, length 20 mm distribution Sikkim .scrobiculata Br.

8. Prothorax punctated sprsely, elytra broadened at hind portion 9

9. Length 25-26 mm very big plumpy species, clypeus small superficially cut and strongly bent inwards, dark-brown, strongly pruinose distribution S. India Male genitatea Fig.117 .... farinosa Nonfr.

   Length 20 mm Prothorax front edge thickly punctated; clypeus bent inwards, clytra with glossy ribs, distribution Sikkim Male genitalia Fig.118 .... seticollis Nose.

10. Elytra with small moderately thick hairs at the margin and apical bump. Prothorax with fine scattered hairs, dark-brown, elytra with spots; clypeus superficially but flatly creanate, forehead with longitudinal furrows, ventral segments very thick with fine hairs, prothorax with a keel

at the base, coarsely pointed and slightly sculptured, elytra without clear flat ribs. Pygidium slightly longitudinally, flat and roughly pointed length 20 mm. distribution N. India Male genitalia Fig. 119.....semihirta Frey.

Prothorax and elytra brown to dark-brown with long hairs, clypeus small without cremation slightly glossy distribution Ceylon ..... setosa Walk.

11. Elytra shiny 12

12. Clypeus semi circular, forehead and crown clearly arch like, punctations on prothorax scattered and rough; Prothorax red, elytra brown spotted, hairs much scattered length 17 mm, distribution Male genitalia Fig. 120..... convexifrons Mosc.

Clypeus clearly crenate; head not arched, thickly punctated, forehead with smooth transverse stripes; prothorax thick, rough, reddish-brown, front edge very thick and finely punctated; elytra parallel, yellowish-brown with fine punctations and scattered long hairs, length 18-22 mm distribution S. Indian Male genitalia, Fig. 121 ..... rufoflava Br.

GROUP II

Elytra thick, without hairs

1. Clypeus constricted at the base, crenate with very deep curves, prothorax with moderately, scattered, punctations, strongly sculptured, length 18 mm. Distribution, North India male genitalia fig. 122. ..... dubiosa Frey.

Clypeus not constricted at the base, even, straight in front or crenate 2

2. Clypeus straight or extremely narrow, rarely flattened, indented in the middle 3

Clypeus rugose 4

3. Fore head arched, very roughly sculptured, Prothorax without smooth flecks, punctations moderately thick slightly sculptured, elytra thick and finely punctated dark-brown. Prothorax, scutellum and humeral callus slightly glassy at the base, claws slender at the base. Length 14 mm. Distribution Ceylon. ..... .inducta Walk.

Fore-head plain, very thick and moderately roughly punctated, so also the remaining head; Prothorax thick or moderately thick, fine at the base with scattered punctation, slightly glossy with smooth central line and two smooth spots in anterior half, claws as in inducta length 14 mm, distribution Nilgiri hills, male genitalia Fig.123..... .... notaticollis Mos.

4. Bigger species, size 22 mm and above 5

Species moderately big from 15 to 20 mm long 11

5. Brown or partly light-brown species, more or less with impressions in the middle of the forehead; prothorax bulged at one side of the base 6

Forehead without impressions; prothorax without hump at the side of the base 9

6. Prothorax with extremely rough, thick and rugose punctations, length 23 mm ..... scrobipennis Br.

Prothorax more or less thick but never with thick and rough punctations 7

7. The side of the Prothorax with distinct bulge, or swelling; clypeus moderately flat, curved, crenate 8

Base of the Prothorax near the hump with a clear Keel; punctations proportionately scattered and moderately rough male genitalia Fig. 126distribution - Sikkim ....sikkimensis Br.

8. Clypeus and forehead with slightly scattered punctations, clypeus small; forehead impression clear; prothorax with scattered rough punctations; Length 23-26 mm distribution North India male genitalia Fig. 124..... cavifrons Br.

Clypeus and forehead with very thick and rough punctations, forehead flat; prothorax moderately thick and finely punctated. Distribution Assam. Length 22-23 mm male genitalia Fig. 125 .... staudingeri Br.

9. Forehead without impressions; prothorax without hump at the side of the base, Prothoraciomargin with deep serrations, clypeus edge much bent up; elytra mostly tomentose length 22-25 mm distribution India and Ceylon, male genitalia Fig. 127.. .....serrata F.

Sym. Ceylonensis Mos.
Serraticollis Mos.

Forehead with impressions Pronotal margin scarcely crenated 10

10. Clypeus edge slightly bent , forehead and vertex with scattered punctations; pronotum at the front with scattered punctation, dark-brown, 25-26 mm long Distribution Nepal ..... Obscura Br.

Clypeus edge bent up, pronotum with scattered punctations; pronotum and vertex with thick punctation dark-brown, 25-27 mm, distribution Himalaya .....sericina Prey.

11. Pronotum at the side of the base with hump 12

Pronotum without swelling at the base, the margin interrupted or broken in the middle 14

12. Forehead and crown with scattered punctations elytra bright, reddish brown, 15 mm long, male genitalia Fig. 128, Distribution - Sikkim ..... biehli Br.

Forehead with thick punctations 13

13. Clypeus moderately rugose, reddish-brown 19-20 mm distribution Bengal male genitatia Fig. 129 .... braeti Br.

Forehead swollen, clypeus lightly rugose, dark-brown 16-20 mm long, male genitalia Fig. 130, Distribution Sikkim .....laticollis Mos.

14. The punctation on the prothorax moderately coarse, pronotal margin even not twisted or cut 15

The punctations of prothorax very coarse pronotal margin twisted, prono[illegible] partly reticularly punctated, elytra thick and coarsely punctated clypeus long and rugose, dark-brown to black but with examples of reddish-brown with the name Cotesi .....anthracina Br.
Syn. Cotesi Br.

15. Clypeus angular not closely curved, head thick prothorax with scattered fine punctations, elytra bright reddish brown 17-18 mm long distribution Bengal, male genitalia Fig. 131.....
..... Clypealis Br.

Clypeus curved, dark-brown mostly pruinose 16

16. Prothora/cic punctations coarser at the front margin than at the base and face 17

Punctations of prothorax equally coarse both at the base and front, outer fore margin thickened
..... 19

17. Clypeus slightly longer, slightly rugose 18-19 mm long. Distribution South India male genitalia Fig. 132..... reynaudi Blanch.
Syn, insularis Br.

Clypeus very small and narrow, strongly bent upwards 18

18. Elytra chestnut 16-1 8 [illegible] distribution North India male genitalia Fig. 248..... consanguinea Blanch

– * Same as above but genitalia differs as in Fig. 139 ..... nathani Frey.

19. Clypeus front margin slightly rugose, slightly bent up in the middle, prothorax pruinose and with scattered, almost uniform punctations. 18 mm long distribution, South India, male genitalia Fig. 134 ..... mucida Gyll.

Same as above but genitalia differs as in Fig. 135 ..... tetarana Br.

20. Clypeus not deeply curved in and in the middle bent up 20

20. Vertex very thick and roughly punctated and punctations clearly more rough than on prothorax 21

Punctations on vertex scarcely coarser than that on prothorax, prothorax irregularly and finely punctated, front thicker on the face; 18-19 mm long distribution South India, male genitalia Fig. 138.....fissa Br.

21. Prothorax and elytra strongly pruinose, 19 mm long, distribution North India male genitalia Fig. 136 ..... pulvinosa sharp

Prothorax and elytra slightly tomentose 19-20 mm long male genitalia Fig. 137..... pagana Drum.

– * Elytra dark-brown 16-19 mm, distribution South India, Malegenitalia Fig. 133 ..... rustica Burm.

GROUP III

1. Prothorax dull; elytra glossy; scutellum tomentose; clypeus very small, very plain and brightly rugose, dark brown, length 16 mm distribution North India .....glabricollis Br.

- Prothorax and elytra s[illegible] 2

2. Clypeus long nearly quadratic, elytra broader posteriorly 3

- Clypeus not elongate, constricted at the base, front upright, circular or crenate 5

3. Clypeus front edge upright 4

- Clypeus front edge triangular, notched, vertex and prothorax sculptured, rugose, yellowish-brown, 13 mm long, distribution North India, Occipitalis Bat.

4. Dark-brown prothorax side projection angular 15 mm long, distribution Kulu, Himalaya .. stolizkae Sh.

.. Light-brown prothorax lateral edge ridge, 18 mm long, distribution Kulu Himalaya .. batillaria Bat.

5. Clypeus clearly constricted at the base 6

- Clypeus not clearly constricted at the base 7

6. Clypeus front edge deeply crenate, two lobed. Prothorax [illegible] moderately thick punctation but roughly sculptured, dark-brown, 18 mm long female shiny male dull, distribution North India. male genitalia Fig. 122..... dubiosa Br.

- Clypeus front edge upright, not lobed, Prothorax with moderately thick punctation but not roughly sculptured, deeply dark-brown including. Head and clypeus length 16-17 mm distribution South India male genitalia Fig.295..... heterotincta Frey.

7. Clypeus slightly circular in the front 8

- Clypeus more or less deeply crenate 11

8. Clypeus upright in the front 9

- Clypeus round in the front 10

9. Length 17 mm, prothorax thick roughly punctated at the sides, dark-brown, elytra not spread posteriorly, male antennal club longer than stem, distribution South India ..... Perotteti B.L.

- Length 13 mm, forehead roughly rugose light-brown, distribution South India .....
..... nilgiria Arrow

10. Front margin of prothorax upright, front corner sharply raised, 10-20 mm long distribution, Ceylon ..... remorata Br.

- Front margin of prothorax concave, front corner shortly raised, distribution Ceylon .disparilis Arr.

11. Prothorax without swelling, forehead in the mid margin of the clypeus with a shallow crenation, elytra with clear ribs 12

- Prothorax at the base with more or less thick, swelling, forehead depressed in the middle or at the junction or at the sides of vertex with deep longitudinal depressions 15

12. Prothorax covered with slightly scattered rough and occasionally fine punctations 13

- Prothorax covered with fine thick symmetrical punctations and the distance from each other vary from 1 to 1½ times 14

13. Forehead and crown very thick with rugose or rough punctations 20 mm long distribution South India .....repetita Ch.

- Forehead and Crown with very scattered punctations and smooth spots, 23 mm long distribution South India ..... madurensis Mos.

14. Prothorax black, elytra light-brown, 16-17 mm long, distribution Himalaya ..... nigricollis Br.

- Prothorax and elytra dark-brown, latter with small fleck, clypeus crenate with flat angles, elytra thick with rough punctations and 3 inconspicuous ribs, pygidium flat and with scattered punctations, distribution Assam ..... rosettae Frey.

15. Forehead with moderately deep impressions in the middle with extremities up to the edge of crown, the impression varies sometime, but always exists, base of prothorax with strong swelling 16

- Crown with deep longitudinal impressions or the forehead flatly depressed on either side 18

16. Elytra parallel, length 20-22 mm, distribution North India ..... Longipennis Bl.
Synonyms tereticollis Bur.
" simlana Br.

- 25-26 mm long 17

17. The last ventral segment of female with a big hook in the centre, clypeus moderately deep crenated; distribution Assam ..... nitida Br.

- Last ventral segment of female normal, somewhat glossy than nitida, clypeus with shallow crenation; distribution Assam male genitalia Fig. 26 ..... assamensis Br.

18. Crown with deep longitudinal depression; prothorax especially with strong sculptures at the sides, well imprinted; 19 mm long; distribution Assam .. ..impressa Bur.

- Crown without longitudinal dipressions forehead depressed flatly at both sides; prothorax swelling, pale-brown to dark-brown, distribution North India, male genitalia Fig. 27 ..frontalis Br. ..... Syn: fulgida Br.

GROUP IV

1. Forehead with wrinkle in the middle or apex; clypeus proportionately cut into two semi-circular halves, punctations very thick and rough; dorsal side dark-brown 2

- Crown with continuous ridge or crest 3

2. Forehead glossy only with scattered rough punctations, apex somewhat fine with thick punctation as clypeus, elytra and prothorax shining, prothorax with irregularly scattered punctations; 14 mm long; distribution North India .....gradatifrons Bat.

- Forehead with very thick and rough rugose punctations as that of clypeus [illegible] crown, prothorax and elytra slightly shining, prothorax thick rough with somewhat irregular punctation, 14-15 mm long distribution Sikkim ..... carinifrons Mos.

3. Length 11-14 mm. Prothorax very thick and rough with rugose punctations 4

- Length 16-17 mm 5

4. Male antennal club as along as the preceding 6 segments, head and prothorax black, elytra dark-brown; length 11-12 mm; distribution South India Fig.143 ..... nigrescense Mos.

- Male antennal club as long as the stem; dorsal side chestnut brown to dark-brown male genitalia Fig.144 distribution South India .... rugaticollis Mos.

5. Head and Prothorax moderately thick and almost proportionately with coarse punctations, dorsal and ventral sides deeply shining, dark-brown; elypeus with small crenations in the centre, both the halves flatly circular; clytra with considerably thick and flat punctations, ribs prominent only by bare stripes, pygidium with moderately thick and rough punctations. Distribution N.W. India .... Fig.145 ..... herteli Crey.

- Forehead, crown and prothorax with exceedingly thick and proportionate punctation; clypeus notch with sharp corners, both halves of clypeus with thick punctations; prothorax dark-brown, elytra

brown, elytra and Scutellum with thick and proportionately moderate coarse punctations without ribs ..... brunneipennis Nos.

GROUP V

Ventral side of thorx nacked, at the most with minute bristles, prothorax with thick to very thick punctations, ventral side partly covered with bristles.

1. Front tibia with three teeth 2
- Front tibia with only two teeth 7

2. Prothorax at the side of the base with clear keel, clypeus with moderately deep crenations, the upward curved margin is reflexed in the centre, prothorax with elongate punctation, 17-18 mm long distribution North India ..... nubiliventris Bat.

- Prothorax without keel at the base, margin discontinuous 3

3. Elytra covered with smooth flakes, entirely irridiscent, front edge of prothorax is broadly rounded 20-22 mm long, distribution Himalaya male genitalio Fig. 146 ..... irridipennis Br.

- Elytra without smooth flecks and not irridiscent, front edge of prothorax not rounded, length maximum 18 mm 4

4. Head with very rough and rugose punctations prothorax essentially slightly coarse, thick punctations on the disk, clypeus with deep crenations, the inward curling sharply angular, both the halves of clypeus bent

at a semi-circle, 18 mm long, distribution South India male genitalia, Fig.147.....
..... sculpticollis Blanch.
Syn: (Sophrops) densicollis Mos.

– Head and Prothorax almost similar with extremely thick and reticulate punctations 5

5. Clypeus with deep crenations, two halves globular shaped, clytra dark-brown, pruinose with inconspicuous ribs, length 16-17 mm, distribution North India male genitalia Fig.153b.....
..... problematica Br.

6. Crenations of clypeus wide, arched, elytra-brown not pruinose, slightly shining, 17 mm long distribution Andaman Islands male genitalia Fig. 148
..... andamana Br.

– Crenations of clypeus sharply angular prothorax and elytra dark-brown, 17 mm long distribution Ceylon ..... .singhalensis Br.

7. Prothorax with rough wrinkled punctations elytra with minute bristles, shape swollen 9-11 mm long, distribution Cylon .....Parva Bur.

– Prothorax extremely thick and finely reticulate or very thick and roughly punctated 8

8. Prothorax with reticulate punctations, dorsal side dull, elytra dark-brown, length 10-12 mm, distribution Ceylon .....puttalana Br.

– Prothorax very thick with very rough punctations, but not reticulate, shining, elytra dark-brown, length 12-15 mm, distribution Ceylon .....
..... eurystoma Bur.

PLATE XXXV

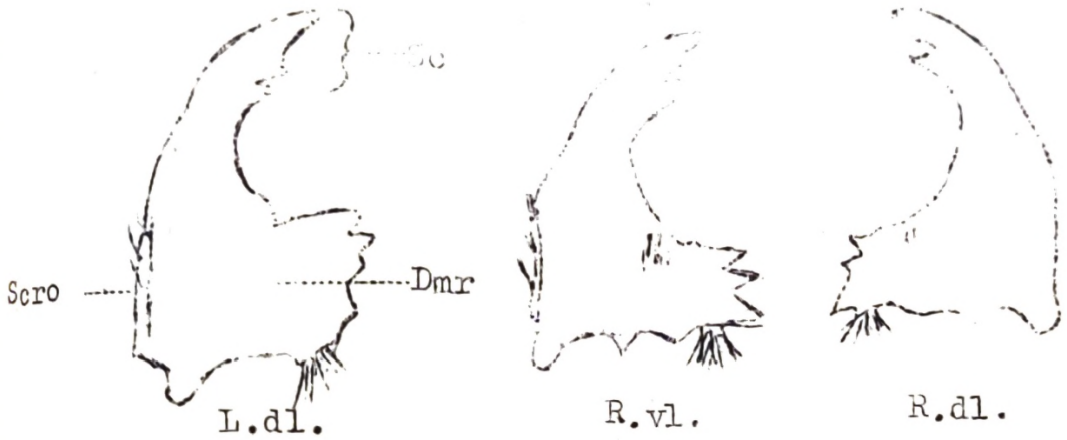

Fig.114

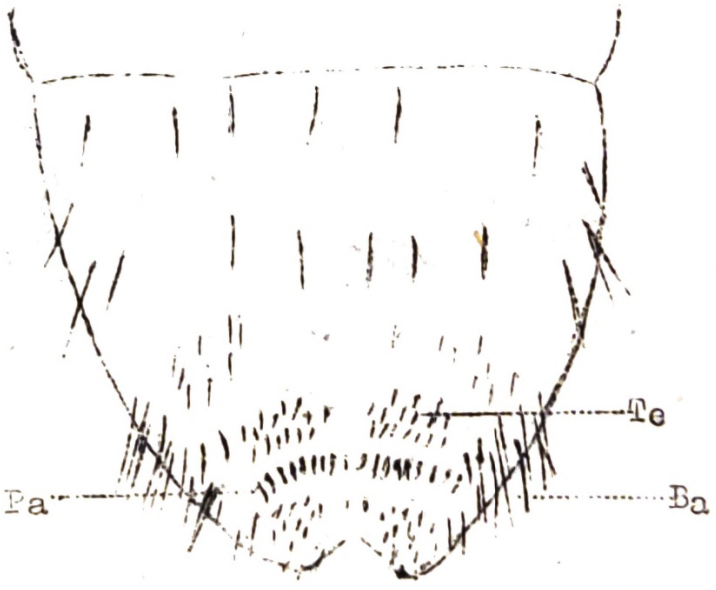

Fig.115

Fig. 116

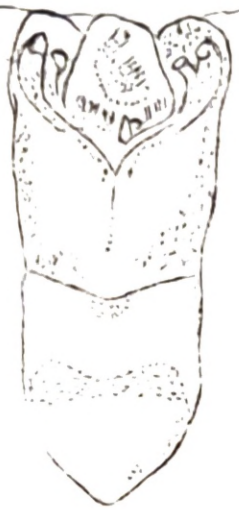

Fig. 117

Fig. 118

Fig. 119

Fig. 120

Fig. 121

Fig. 122

Fig. 123

Fig. 124

Fig. 125

Fig. 126

Fig. 127

PLATE: XXXVIII

Fig. 143

Fig. 142

Fig. 141

Fig. 140

Fig. 144

Fig. 145

Fig. 146

Fig. 147

Fig. 148

Fig. 149

Fig. 150

Fig. 151

Fig. 152

Fig. 153a.

Fig. 153b.

PLATE: XXXVII

Fig. 128

Fig. 129

Fig. 130

Fig. 131

Fig. 132

Fig. 133

Fig. 134

Fig. 135

Fig. 136

Fig. 137

Fig. 138

Fig. 139

BIONOMICS AND CONTROL

There are nearly 200 species of white grubs in the sub-families Melolonthinae, Rutelinae, Dynastinae and Cetoniinae of the family Scarabaeidae which are economically injurious to crops in India either in their adult stage or in larval stage or both.

Literature reviewed and data collected during last 15 years revealed that the causes for white grub outbreak were mostly man made.

The seriousness of the problem of white grubs to cultivated crops was not realised until 1956, when a serious outbreak of white grub was reported on sugarcane in Dhalmianagar, Bihar. If the number of publication on white grubs and their management in India is any indication to the magnitude of the problem now and before two decades, certainly the problem has increased in the last two decades. Realizing the importance of white grubs in Indian Agriculture, the Indian Council of Agricultural Research constituted a committee of experts in 1974 to consider the problem and to suggest corrective measures, as a result of which a number Adhoc project were sanctioned and now an All India Co-ordinated Research project on white grub is in operation.

Two decades back traditional agriculture in India closely followed the monsoon pattern. White grub life cycle and the preparation of land and sowing coinsided with the on set of rains. The annual life cycle of the pest started with egg laying after the premonsoon rains when preparatory cultiva-

tion also started. During tillage operations like ploughing, harrowing and sowing, grubs were reduced to a minimum due to predation or injury. But with the shift in the cultivation practices brought about by the introduction of high yielding varieties, artificial irrigation, monoculturing, relay cropping more favourable conditions for the white grubs multiplication was created. Inherently either the adults or grub are not capable of migrating long distances, but due to fast developing transport systems, the pest was carried all over inadvertantly. The cultivable land has been doubled to 170 million hectares during last 25 years and irrigation was extended from 18 percent to 25 percent of cultivated land. White grubs subjected to Nature's vagaries were surviving on natural vegetation but suddenly increased in situations when more favourable conditions were created.

Bionomics:

In India the white grubs have one year life cycle. In western hemisphere they take 3 to 5 years to complete their life cycle. The different species of white grubs have similar pattern of life cycle in India but may vary, according to the climatic factors, in their time of emergence, egg laying, active larval period, time of pupation etc., not only at different parts of the country but also at different places in an ecosystem. The same species differ in its time of emergence from place to place depending upon the first rains of April-June. For example adults of H.serrata emerge in the first week of April in South India and late in June in Northern India, because of the difference in the receipt of rain.

Holotrichia serrata emerges from the soil in the evening between 7-30 to 8-30 P.M. after the first summer rains (All

chafers have more or less similar pattern of emergence). After emergence the adults mate and feed and get back to the soil before dawn. The adults do not go too far from the place of their emergence and generally get into the soil from where they emerge particularly around the host plants. Egg laying starts soon and may last for 2-3 weeks. A single female lays 25 to 30 eggs. Eggs are laid in the soil enclosed in earthern cells at 8 to 10 cm deep. Egg pearly white, oval in the beginning and later turn spherical. Incubation 10 to 12 days

Newly hatched grub creamy white, 10 to 11 mm in length. It mostly feeds on the organic matter available in the soil. The grub comes out of the earthern cell if sufficient moisture is present. Otherwise it can remain quiescent inside the cell for over 4 months under drought condition and can revive on the onset of favourable condition. The second and third instars are active root feeders, 'C' shaped, and measure on an average 28 mm and 47 mm respectively. The 3 larval instars occupy on an average 30, 35 and 102 days. Under adverse conditions, the grub of any stage can become quiescent until favourable condition prevail. Complete saturated condition of the soil for 7 days is detrimental to the grubs.

The larva of the different species can be identified only based on the morphological characters of labrum, clypeus, cranium, mandibles, maxilla, epipharynx and rasher

Pupation generally occurs during November-December under Karnataka conditions, but it may occur any time between September and February depending upon the availability of food and other ecological conditions. Pupal period 12 days, Before pupation the larva goes deeper 20 to 25 cm, construct earthern cell in which it lies quietly for some time

Though the formation of the adult is seen some time during November-December itself, it lies in the earthern cell until the first summer rains in April-May, thus in some cases the adults will be lying insde the soil in earthern cell for well over 6 months.

Natural enemies:

The milky disease (bacterial) and the muscardine (fungal) are important controlling agents in nature. In addition predacious birds like crows, mynahs, feed on grubs during tillage. Pigs are fond of these grubs. Toads feed on adults. The insect parasites like Tiphia spp. and Scolia spp. though recorded on grubs, seldom act as controlling agents. A new fungal parasite Beauveria brongniartii is recorded for the first time in India, and is found to be one of the important controlling agent in this state.

Control.

An effective control of root grub is possible only when the pest is managed from egg to adult adopting several methods. No single method can give cent percent control except puddling

and paddy cultivation. Some of the methods to be adopted in controlling the root grubs are listed below. Any method to be effective should besuitably timed closely linked with the life cycle of the pest.

1) Since the adult emergence is rigidly set in respect of time, (7.30-9.00 PM), the adults can be easily collected in very large number with the help of a petromax light, on the same and following days after the first rains in summer, thus contributing largely for the control of the pest before egg laying. This measure however, may not be very effective over a large area under planted condition. Adult collection to be effective as a measure of control should be done for a week from the first day of adult emergence, collectively by all people concerned.

2) The adults have a few preferred hosts like neem, Pithecalobium etc. Such trees if present on the bunds, or branches of such trees cut and planted on the bunds after the dusk on the day of the first rains when adult come and collect on them which can be collected and destroyed.

3) Application of insecticides, in order to be effective, should be done immediately after the first rains. Phorate 10 g (10 kg/acre) or carbofuron 3 g (10 kg/hec.) or quinolphos (Ekalux 5 g, 10 kg/acre) or disulfoton 5 g. (Disyston, Solvirex 12 kg/acre), applied uniformly over the infested area and mixed into the top soil, gives good control of grubs. Application of these chemicals under standing crop and also when the grubs are grown up will not help in controlling the grubs even if the dosage is doubled.

4) Giving one or two ploughing upto 25-30 cms, after the harvest during January will expose the hibernating adults and will kill them. This will reduce the population to a great extent for the next season.

5. Biological control of white grubs:

I. Using pathogens: Muscardine disease of white grubs:

The newly discovered fungal pathogen Beauveria brongniartii Sacc. (Ranganathaiah et al., 1973) was further studied intensively in addition to the studies of other muscardine fungi. Studies on mass culture its utilization in the integrated management of white grub Holotrichia serrata F, its pathogenicity to silkworm were conducted and the results are summarised as follows:

1. During the course of investigation three species of muscardine fungi, namely B. brongniartii, B. bassiana and M. anisopliae were recorded on white grubs from Karnataka. The incidence of the disease varied from 0.5 to 7.0 per cent and it was higher in rainy season. Cultural and morphological characters have been studied and a key has been developed for easy separation of the fungi.

2. In addition to hosts already on record, the following new addition of hosts have been added to the host list of B. brongniartii: H. farinosa, H. rufoflava, H. nilgiria, Schizonycha ruficollis, Apogonia rauca, A. ferruginea, Aphodius insularis, Mimela macleayana, Anomala bengalensis, A. ruficapilla, Adoretus versutus, A. bicolor, Cetonia sp., Heliothis armigera, Plusia spp. Cephalocrocis medinalis. Holotrichia serrata,

7. The viability of the spores was higher at 15°C (60.75 per cent) and was less at 35°C (6.69 per cent). The relative humidity which kept the spores viable for long was 95 to 96 per cent as compared to others. In general the loss of viability was higher in younger spores compared to older spores, which lost it gradually with increase in age.

The interaction of temperature and relative humidity was significant. The viability of the spores decreased with increase in temperature at all humidity ranges tested. The temperatures between 15-30°C, the increase of humidity from 33-40 to 69-75 per cent considerably reduced the spore viability and further increasing it from 69-75 per cent to 95-96 per cent considerably increased the viability of the spores. So much so the bad effects of higher temperature could be minimised by maintaining higher humidity. Nevertheless, lower temperature coupled with higher humidity favoured the survival of the spores for a longer period.

The interaction of temperature and age of the spores was also significant. At all temperature levels the viability of the spores decreased with increase in age of the spores. However, the rate of decrease in viability was faster at higher temperatures compared to lower temperatures with advance in age of the spores.

A. bengalensis and A. bicolor, were now for B. bassiana while H. serrata, A. rauca and A. bengalensis for M. anisopliae.

3. Symptoms of infection of B. brongniartii were studied on all the stages of both white grub and silkworm and were described.

4. Cultural characteristics studied on twelve agar and broth media revealed Sabouraud's Maltose media as best for both the growth and sporulation of the fungus.

5. Germination of spores studied in nine liquid solutions at 6 h intervals for 72 h indicated that the maltose 2 per cent solution as good by registering 35 per cent and cent per cent germination by 6 h and 54 h of incubation, respectively.

6. Radial growth of the fungus was superior at 20°C (12.95 cm) and at a relative humidity of 69 to 75 per cent (5.25 cm) compared to other temperatures and relative humidities. The sporulation was good at 25°C (9.63 lakhs/pl) and the relative humidity favourable for it was 69-75 per cent (6.54 lakhs/ml) compared to other temperatures and relative humidities. However, the germination of the spores was better at 30°C (90.25 per cent) and relative humidity best suited was 86 to 93 per cent (90.33 per cent) but other temperatures and humidities gave less percentage of germination of the spores.

The effect of humidity and time (age) was marked. On the whole higher humidity ranges maintained the viability of the spores relatively for a longer period compared to lower or moderate relative humidities. Approximately 75 per cent of the spores became inviable in 13 weeks at 33-40 per cent relative humidity, in nine weeks at 52-56 per cent relative humidity, seven weeks at 69-75 per cent relative humidity, in 17 weeks at 86-93 per cent relative humidity and in 20 weeks at 95-96 per cent relative humidity. The study also indicated that 50 per cent of the spores lost ranges of 33-40 to 69-75 per cent, while at higher relative humidity ranges the spores became less viable at a slower rate.

The interaction of temperature, humidity and time was also highly significant at all levels tested with regard to the viability.

In all the ranges relative humidity and temperature ageing substantially reduced the spore viability. Enhancing the temperature or decreasing the relative humidity reduced the viability of the spores. The adverse effects of higher temperatures on spore viability could be minimised by providing either higher relative humidity at higher temperature or lower humidity at lower temperature.

8. The fungus yielded maximum spores in barley grains (2.673 lakhs/ml) compared to others (0.770 to 1.950 lakhs/ml) and between plain and honey peptone treated grains, plain grains proved (1.936 lakhs/ml) superior over treated grains (1.603 lakhs/ml) and barley grains could be utilised for mass production of the fungus for utilization in the control of white grub.

9. Of the different methods tested, the broadcasting method of application of the fungal spores with organic manure proved superior for the control of white grub.

The use of pig manure as carrier for the application of the fungus found superior to other manures by giving higher rate of protection to plants.

10. The application of fungal spores at the rate to give 10^5 spores per g of soil and 50 g of 50 per cent BHC per m^2 area found good for the reduction of first instar grubs but for the reduction of second and the third instar grubs the use of fungal spores at the rate to give 10^9 spores per g of soil appeared good.

Among the various concentrations of the fungal spores, 10^9 spores per g of soil gave higher protection to plants due to white grub compared to lower dose of

fungal spores and even standard insecticide recommended for white grub control.

Studies carried out on the influence of combination of various factors (fungus, manure, insecticide and pest population density) revealed that all combinations were markedly superior to check in reducing the white grub population.

Even with regard to fresh pod yield of groundnut, there was significant difference between the check and other treatment combinations.

11. The fungus was infective to silkworm of all instars and affected the economic characters in them. Increasing the spore concentration increased the mortality in all instars and the economic characters deteriorated progressively in the successive moults. The mortality rate varied considerably due to the infection of the fungus in different races of silkworm and the race J_{22} was highly susceptible for the infection compared to other races.

II. Milky disease of white grubs:

The widely known milky disease bacteria Bacillus popillae Dutky was studied on white grubs concentrating mainly on methods of inoculation, symptomtology, Mass culturing and field application.

Among the different methods of inoculation used for inducing the disease, the highest disease incidence was found through potato feeding (84 per cent) followed through carrot feeding (76 per cent), soil inoculation (74 per cent), root dipping method (70.6 per cent), grub dipping method (56 per cent) and then topical application (8 per cent). Grubs treated by intra haemococlic injection died before producing disease symptoms.

The average number of days required to produce 50 per cent disease incidence at 10^8 spore concentration was 13.84, 15.85, 16.98, 19.05 and 25.12 days in potato feeding, soil inoculation, root dipping particularly bengalgram, carrot feeding and grub dipping. Thus it was least in potato feeding. Maximum number of 39.18 days were required to get 50 per cent disease incidence in grub dipping at 10^6 concentration.

The symptoms of milky disease studied in all stages of root grub did not show any symptoms in eggs while the larvae turned milky white in appearance as the disease progressed obscuring the rectal sac. The legs became opaque. The diseased larvae were soft and did not respond to any tactile stimulation, stopped feeding and stayed at the bottom of the rearing box and ultimately died. The cadavers turned black and rigid. Most of the diseased larvae succumbed before

pupating, thus no pupae and adults were available for observation.

Among the four media used for culturing, Steinkraus's Growth Medium was found most suitable. The colonies formed were tiny and colourless. These colonies consisted of only vegetative cells and did not produce spores, indicating that the medium can support vegetative growth but not spore formation.

The vegetative cells were rod shaped and measured 0.295 x 3.285 μ. The spores were typically foot print shaped and measured 1.34 x 3.67 μ. They were gram positive and aerobic.

The spores germinated within 24 - 25 hours and formed vegetative cells. The vegetative cells multiplied when they were still attached to the spore and also when they were separated from the spore.

The bacteria took 21 days from spore to spore. The entry of spore was either through ingestion or wound which germinated into vegetative cells in the healthy grub and formed into spores at the end of 21 days. was dispersed in the soil when the grub died and disintegrated.

There was linear relationship between temperature and the disease development. The optimum temperature

for disease development was 30°C, which produced 80 per cent of the disease incidence. At higher temperature of 35°C there was natural mortality of 43 per cent.

A spore concentration of 10^8 dipped in potato and sown in the field was found inducing disease in the grubs further, studies on its utilization in large scale field application is in progress.

6. Integrated control of white grub, H.serrata F.

Integrated control including Mechanical control (adult collection), Chemical control, and cultural method (ploughing, host attraction) were tested in combination and individually for the management of H.serrata.

The study conducted on beetle collection revealed that, the peak emergence of the beetles was on the first day after the first summer rain. A total number of 5,86,000 beetles were collected in an area of over 40 hectares, in 13 days. The pattern of beetles collected was 56, 84.62 and 90 per cent in first four, eight and 10 days following the first summer rain. The highest number of beetles (1,04,000) were collected on the first day after the first summer rain followed by second and third day with 88,000 and 56,000 respectively. There was a second peak emergence with 80,000 and 64,000

beetles on the first and second day after the second rain after a gap of three days.

Beetle collection was compared with insecticide application (phorate 10 G at 15, 20 and 25 kg/ha) with repeated ploughing, repeated ploughing alone and untreated check. The average number of first instar grubs per sq.m were 4.84, 5.38, 7.53, 5.91, 45.69, 46.59 in respect of phorate 10 G at 25, 20 and 15 kg/ha with repeated ploughing, beetle collection, repeated ploughing alone and untreated check respectively. The reduction in grub population when compared to untreated check was 90, 88, 85 and 87 per cent in respect of phorate at 25, 20 and 15 kg/ha with repreated ploughing and beetle collection. There was no reduction of grub population in repeated ploughing without insecticide and untreated check.

Study conducted on host preference of grubs revealed that there was no evidence of grubs having any particular preference to any crop tried, although garlic and ridge gourd attracted least number of grubs. After 30 days of sowing ridge gourd plant registered the lowest mortality (6.25 per cent) followed by garlic (19.29 per cent), maize (23.57 per cent), onion (34.5 per cent) and groundnut (52.08 per cent). After 45 days of sowing on an average 17.5, 15.25, 13.5, 10.25, 9.0

and 6.25 live grubs were found in respect of maize, groundnut, onion, ridge gourd, cheek and garlic respectively.

Some of the new and commonly used soil insecticides like, phorate 10 G, terbufos 5 G, carbofuran 3 G and aldicarb 10 G at 25 kg/ha, chlorpyrifos 20 EC at five litres/ha, chlordane 20 EC at 10 litres/ha and mahua cake at 100 kg/ha were tried against second and third instar grubs. All these insecticides failed to give satisfactory control against the third instar grubs but on second instar grubs phorate, terbufos and chlorpyrifos gave effective control.

In an experiment on comparative efficacy of different methods of control, insecticide (phorate 10 G) at different levels (15, 20 and 25 kg/ha) combined with repeated ploughing gave the best result. Based on the number of first instar live grubs per square meter, the combination of insecticide with repeated ploughing was on par with that of beetle collection alone. Since repeated ploughing against first instar grubs was not effective, integration of beetle collection immediately after the first summer rain followed by application of insecticide at lower dosage (phorate 15 kg/ha), giving one ploughing before and one after application of insecticide to mix thoroughly was found effective against grubs.

Cost of different methods of white grub control showed that beetle collection after first summer rain with application of insecticide (phorate 10 G 15 kg/ha) at half the recommended dosage two to three weeks after the first summer rains is economical and effective.

7. Dispersal and Migration of Holotrichia serrata

A study was undertaken to know the dispersal and migration of H.serrata in relation to its abundance. The studies involved two aspects - 1) Dispersal and migration of adults, 2) Larval migration.

Marking of the adults for dispersal and migration studies was made with nail polish, fluorescent powders, fluorescent lacquers, indelible ink and camel black ink. The first three were found suitable and lasted long. Indelible ink was lethal to beetles. The peak of emergence of marked and released beetles was from 19.25 hr to 19.45 hr. During calm nights, beetles were active throughout night on host plants like neem and return journey was around 5 hr in the morning. There was not much activity of beetles on the days with high wind or continuous rain. The maximum number of beetles were recovered at distances ranging from 50 to 200 m on host plants planted for the purpose. Maximum distance flown by any single beetle at a stretch was 400 m to a host plant from the place of release.

During subsequent days beetles were recovered at distances of 590 and 660 m to light sources from the point of release. Light sources during nights, seems to influence migration of beetles in addition to preferred host plants. Beetles, generally flew in the direction of the wind when wind speed was 10 to 12 km per hour. Marked beetles were recovered upto fourth day of release during nights.

Under controlled experiment (Quadrate box), more number of grubs were recovered in the box with plants at 60 cm and 127.5 cm apart, compared to the boxes with no plants and one plant at the end of the box at 255 cm. However, larvae went to any direction at the time of pupation irrespective of the availability of plants. Average distance migrated by the larvae in box with red soil from hatching to pupation was 640.9 and 1109.5 cm during 1977 and 1978 respectively. Migration of grubs till pupation in gravelly soil was about 40 per cent less compared to that of black soil. Per cent survival of grubs in gravelly, black and red soil was 72.0, 70.8 and 91.4 respectively.

Larval migration in the lawn was less compared to migration under crops. Average distance travelled by the larvae from hatching to pupation in the lawn was 151.2 cm, the minimum and maximum being 100 and 240 cm respectively and vertical migration was upto 12.9 cm.

In the cultivated field, average distance travelled was 408.3 cm, the maximum being 660 cm, minimum and maximum depth at which they pupated in cultivated soil was 14.0 and 19.7 cm respectively. Onion, groundnut and frenchbean were comparatively more preferred host plants and the ridgegourd was the least affected. Generally, third instar grubs did not move towards soil with no plants. The horizontal migration gradually increased from first to third instar and ceased before pupation. Similarly, vertical migration gradually increased from first instar to third instar depending on the root system and moisture level. The larvae before pupation moved downward where it pupated and this depended on the type of soil, soil moisture and vegetation under field condition.

STUDIES ON THE WHITE GRUB HOLOTRICHIA CONSANGUI...

C.P.S KADAVA*

INTRODUCTION

White grub, Holotrichia consanguinea Blanch. is the most destructive post of almost all crops grown during rainy season. Some times early sown Rabi (winter) crops are also affected during early parts of their growth. The grubs of the pest feed on the roots of the plant and cause severe damage by nibbling the entire root system. The affected plants first show symptoms of wilting and ultimately dry up. The adult beetles assemble in large numbers and defoliate several kinds of host trees, notable among them are listed below.

S.No.	Common name	Scientific name
1.	Almond	Prunus amygdalus
2.	Amaltas	C... fistula
3.	Arhar	Cajanus cajan
4.	Arjuna	T...ia arjuna
5.	Banyan	Ficus bengalensis
6.	Ber	Zizyphus rotundifolia
7.	Citrus	Citrus spp.
8.	Falsa	Grewia asiatica
9.	Guava	Psi...ium gujava
10.	Gular	Ficus glomerata
11.	Gulmohar	Delonix regia
12.	Jamun	Avgenia jambolana

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13.	Karonda	Carisa carandas
14.	Khejari	Prosopis specigera
15.	Mango	Mangifer indica
16.	Mulberry	Morus spp.
17.	Neem	Azadirachta indica
18.	Palas	Butea monosperma
19.	Peach	Prunus persica
20.	Pear	Pyrus communis
21.	Pipal	Ficus religiosa
22.	Pomegranate	Punica granatum
23.	Roonjh	Acacia leucophloea
24.	Rose	Rosa indica
25.	Rukmanjini	Lagerstonia indica
26.	Sanjana	Moringa elifera
27.	Shisham	Dalbergia sissoo
28.	Silver Oak	Grevillea robusta

The grubs are polyphagous, feed on the roots of a wide variety of crops and grasses.

The pest is widely distributed in India. It is common and predominent pest species in areas having sandy soil and moderate rainfall. Heavy soils are not suitable for this species. The grubs cause damage to various crops in major parts of Rajasthan, some districts of Gujarat, Punjab, Bihar, Uttar Pradesh and Andhra Pradesh.

This species of white grub has acquired a considerable importance in the State of Rajasthan and is causing damage in several pockets of the districts of Jaipur, Ajmer, Sikar, Jhunjhunu, Nagaur, Jodhpur, Pali, Bhilwara, Chittor, Udaipur, Sawai Madhopur, Bharatpur, Alwar and Tonk. In Rajasthan the damage caused to different Kharif crops varies from 10 to 100 percent.

Emergence: Rainfall and atmospheric humidity play the most significant role in the emergence of beetles and drought delays the emergence so far as time and number of beetles are concerned. Though the beetles may emerge in small numbers after the 2nd week of May, their first emergence occurs only after the good pre-monsoon shower and second emergence occurs after the onset of the mansoon. For a good emergence about 28 mm rain is required. However, even less than this may cause some beetles to emerge. Heavy rains received prior to middle of May, may not cause the beetles to emerge as they are not sexually mature before this period. Some stray beetles have been reported to emerge in April, following irrigation of the fields. Such beetles are either very few in number or these have been incorrectly identified. In Rajasthan, Holotrichia serrata beetles have been observed emerging in April and they are confused often for Holotrichia consanguinea. The beetles of H. consanguinea emerge during dusk between 7.45 - 8.00 P.M. in Rajasthan.

Their emergence is related to definite light intensity. The beetles do not prefer too dark or bright light. Therefore, their emergence is timed with the sun-set and sun rise. During May the emergence time may be 7.45 and towards the end of June it may be 8.00 P.M. However, if there is a cloudy evening the emergence may occur few minutes earlier as the required light intensity (darkness) prevails earlier than the normal time. In laboratory the daily emergence time of the beetles can be changed by shifting the light and dark hours to either side. These timings may also change by few minutes depending upon the region of the country where observation is made. For example on the same date the emergence time in Bihar will be different from Rajasthan, as we maintain the same time in our clock through out the country irrespective of sun-rise and sun-set timings. However, if we fix the light intensity (darkness) as the base, the emergence will always be at a fixed light intensity, irrespective of the region of the country or month of the year.

It may not be out of place to mention that beetles have adopted to these light intensity-hours for their daily emergence because of few definite reasons. If they emerge early, they will be predated upon by birds many of whom are very fond of them. If they emerge late they will not be able to perceive host during

darkness. It has been observed that females emerge first and then male comes out, hover around the tree and comes in close vicinity of the female following a pheronone odour but then the flight straight on the back of the female which is possible only due to visual perception. In too dark evening the visual perception is not possible and finding of suitable female will be difficult. Similarly, the beetles which are not interested in mating but want to feed on host, also determine the presence of the host in the horizon by seeing the silhoutte which is visible in a definite light intensity only. If it becomes too dark the silhoutte of the tree is not perceived visually and beetles are not able to reach the host. These observations can be further confirmed by the fact that during dark night after about 8.00 P.M. if the beetles are jerked from the tree they fall on the ground and either enter into the soil or fly towards a light, but are unable to settle down on a host tree. Once the beetles have emerged following a good rain, they continue their daily visit to host in the evening as long as, the atmospheric humidity remains high. If there is no subsequent rain and atmospheric humidity goes down, the daily visit (emergence) of beetles gradually goes down and only few beetles are observed on the hosts. Such a situation is observed usually after a premonsoon rain. However, after the regular monsoon i.e., in the

month of late June or July - if the emergence is followed by drought but the atmospheric humidity is high beetles will continue to make daily emergence in the same number continuously for a period ranging from 4 to 6 weeks. Gradually these beetles will perish after completing their mating and egg-laying. Temperature does not appear to play a deciding role on the daily emergence. However, the sun shine hour is indirectly proportional to emergence i.e., lower the sun shine hour during the day, higher will be the emergence of beetle during the evening.

2. Host trees of beetles - The beetles are polyphagous and have been observed to feed on a wide variety of hosts. However, some host preference is exhibited by the beetles. In areas of Rajasthan where Ber, Khejari and Neem are available together, Ber is preferred over Khejari and Khejari is preferred over Neem. In an area where Ber, Neem and Gular are available together, Ber is preferred over Gular and Gular over Neem. In the areas where population of beetles is very high, it may appear that there is no host preference and beetles can be seen feeding on a large number of hosts in the s locality. However, if the beetle population is low, a distinct host preference among the available host trees can be seen. In many localities, where beetle population is not very high and other hosts are available

beetles may not feed on Neem at all. Contrary to this in some other areas where no other preferred host is available, Neem trees may be completely defoliated. In Rajasthan some of the host combinations and order of preference is as under :

Host combination	Order of preference
Ber, Neem, Khejari	Ber Khejari Neem
Ber, Gular, Neem	Ber Gular Neem
Ber, Sainjana, Khejari, Neem	Ber Sainjana Khejari
Ber, Gulmohar, Khejari, Neem	Ber Gulmohar Khejari Neem
Karaunda, Neem, Guava	Guava, Karaunda Neem
Babul, Neem, Khejari	Kehjari Neem Babul
Eucalyptus, Babul, Khejari	Khejari Educalypties Babul
Gular, Babul, Neem	Gular Neem Bagul
Ber (deshi), Ber (Jhari), Ber (Pemli)	Ber (deshi Ber (Jhari) Ber (Pemli)
Ber (Pemli), Sainjana, Khejri	Sainjana Khejari Ber
Ber, Neem, Roonj, Khejari	Ber Ronj Khejri Neem
Khejari and Roonj	Roonj Khejari

It can also be observed that in the same location among the trees of the same species some are more liked as compared to others. Many times some trees are wrongly identified as hosts as beetles in over populated areas soonafter their emergence try to settle down on any tree

available nearby for mating. Soon after mating, such beetles leave these trees and fly to the food trees where they continue feeding throughout the night. Since the mating (finding of suitable mate) is possible during the period of 10-15 minutes immediately after the emergence, beetles do not try to waste the time in searching out a preferred food tree but try to mate on any tree which provides them support for mating and later they try to find the food plants. Such trees should not be considered as a host.

Mating - The female is first to come out of the soil in the evening and settle on a tree quietly. Such female then projects out a part of its external genitalia and releases a pheromone. The males follow the odour, hover around the tree having such receptive females and one of the males comes in close vicinity of a female and alights directly on her back. From the behaviour of the male it appears that to reach in close vicinity of a female pheromone is necessary but to locate exactly and to alight on the back of the female, visual perception is used. This is why pairing is possible only during the first 5-10 minutes of emergence in the twi-light when pres of beetle is seen from a close range. Later, when it becomes dark, no pairing occurs and many females, though desirous to mate, when fail to attract a male during first few minutes, remain alone and unmated on that

evening. Such females, try mating next evening. This is why the mating continues over a period of 3 to 4 weeks or more, though the number of mating pairs decreases gradually. During the process of mating the male rides over the back of female and holds the female by its first pair of legs. By slight movement, the male inserts its protruded aedeagus in the genitalia of the female. Soonafter this, the male gives up the hold of female and assumes a downward position, only 3rd pair of legs being in contact with the hind pair of legs of female till copulation is over. The mating lasts from 7 to 16 minutes.

During copulation none of the mating partners feed on the host tree. After the copulation the male gently gets separated and either flies away to some other host tree or settles nearby on the same twig. Thus, after mating both the partners feed for the whole night on the tree provided it happens to be the host of the beetle. If the tree on which mating occurs happens to be a non-host, the beetles after copulation fly to the host tree nearby and stay on it overnight for feeding till early morning.

Eggs - The eggs are laid singly in soil at a depth of 15 - 20 cm in instalments. The egg laying begins after 2 days of mating and may continue for several days. All

eggs are not laid on one day. In some situations, a female may lay few eggs on one day and may not lay for another 3 to 4 weeks and may lay again few eggs, in laboratory. Wide variations exist between individual female with regard to days on which eggs are laid and also the number of eggs laid on each day. Total number of eggs laid by a female in laboratory may vary from 1 to 30 or more with an average of 8.5. Though feeding of female on host is not necessary for egg laying, females which are not allowed to feed lay relatively less number of eggs as compared to those, which are allowed to feed on the host. Freshly laid eggs are white, elliptical about 3.22 mm in length and 1.9 mm in width, but after 3rd or 4th day onward the eggs embibe moisture from the soil and become globular. Prior to hatching they become brownish black in colour. The incubation period under laboratory conditions (32°C and 62 % R.H.) varies from 7 to 13 days.

Grub - There are three larval instars. The larvae are 'C' shaped. The newly hatched grub is creamy white in colour having brown head, the head length and width being 4 mm and 3 mm respectively. It measures 10.1 mm in length. These grubs are less active and feed on small rootlets of crop growing in the field. In absence of living roots the grubs of 1st instar can feed on organic matter present in the soil for some days. The first instar larvae when allowed to feed on organic manure alone

in laboratory conditions (34°C 65 % rh) may survive from 5 to 28 days. Some of these reach second instar but die later on. The duration of first instar is 13 - 19 days.

The 2nd instar grub is about 25.5 mm in length. The head length and width being 6 mm and 5 mm respectively. The duration of 2nd instar is about 25 to 39 days.

The 3rd instar grub measures 40.7 mm in length. The head length and width being 8 mm and 7 mm respectively. The duration varies from 44 to 55 days. Total grub duration ranges from 82 - 113 days.

Pupa - The fully grown grub stops feeding, makes an earthen cell by pushing the soil around it for pupation. The 'C' shaped grub gradually straightens and then transform into an exarate pupa. The newly formed pupa is light yellow coloured and gradually changes to brown towards the transformation to adult. It measure 27.3 mm and 14.2 mm in length and width respectively. The pupal period ranges from 11 to 18 days with an average of 14 days under laboratory conditions (29°C 80 rh).

Imago - The freshly emerged imago is white in colour and with lapse of time it becomes dull brown with light brown abdomen and dark brown legs. The average beetle length and width is 21.3 and 11.8 mm respectively. The duration of one life cycle from egg to adult on an average is 133 days and there is only one generation in a year.

PREOVIPOSITION, OVIPOSITION PERIOD & LONGEVITY OF BEETLES

Wide variations exist in preoviposition, oviposition and post-oviposition period. The longevity of male and female after the first (premonsoon) emergence from soil is about 35 and 39 days respectively and is about 45 and 49 days respectively after regular monsoon emergence in Rajasthan conditions. The longevity of female is reduced when they are deprived of food.

Flight range of beetles - The beetles do not fly long distance, after the emergence from the soil. They have the habit or desire to reach the nearest available host for mating or feeding during the definite light intensity prevailing in the evening which is available for few minutes only. Therefore, long distance flights are not observed. The normal flight distance could be 70 - 100 M in areas where hosts are available. In the morning, the beetle retire into the soil within a close range and do not fly long distances, hence the grub population is inversely proportional to the distance from the host. However, just underneath the host the beetles do not retire and hence, the population just underneath the tree may be less.

Attraction of beetles to light

A very small percentage of beetles are attracted towards the light. The beetles trapped in Ultraviolet light, 20W Flourescent tube-light, 80W Mercury Vapour Lamp light,

80W MLL Bulb light and 100W Bulb light were 3.4, 2.4, 0.9, 0.8 and 2.0 per cent, respectively. It may, therefore, not be feasible to employ such light trappings for the control of beetles. However, the trap fitted with either Ultraviolet or Flourescent or incandescent bulb may successfully be used for survey work and for finding seasonal fluctuations of beetle population.

It may be interesting to note that the maximum number of beetles are attracted towards the light between 8.30 to 9.30 p.m. If there is rain after the beetles have settled on the host a number of beetles leave the host and move towards the light source. If there is rain in the evening prior to emergence time and soil surface becomes wet, very few beetles would emerge on that evening. The number of beetles emerging during windy evenings is less as compared to calm and warm evenings.

Preference of soil type for oviposition

Females prefer to lay eggs in loamy sand soil followed by sandy loam whereas clay soil is not preferred at all. Moreover, sandy soil is liked for oviposition as compared to F.Y.M. alone or F.Y.M. mixed with sandy soil. Heaps of manure do not attract the females for egg laying, however, a sandy soil surface where F.Y.M. is spread may be preferred over the manure heaped surface.

It is interesting that the maximum survival of the grubs is found at 7.2 pH of the soil whereas it is very low at 10.1 and 5.9 pH.

Seasonal History - The diapausing / over wintering beetles emerge from the soil mostly in the middle of May following pre-monsoon or monsoon rains. The emergence of beetles may continue upto July or early August depending upon the rain and stmospheric humidity. The beetles soonafter emergence start mating on the tree in the evening. Thus, mated females start laying eggs during day time in cultivated or uncultivated soil provided the soil is sandy. The eggs hatch after about 8 - 10 days and the newly emerged larvae begin to feed on organic matter present in the soil and then move to the living roots of plants which are available in the soil. Three instars of the grubs are completed in about 82 - 113 days if living roots are available in the soil.

During developmental period (June - September) majority of grubs stay between 10 - 20 cm soil depth (Table 6). The grubs of different ages can be seen at one time because of the variations in the time of emergence and egg laying of the females. In the month of September some grubs can be observed moving down to a depth of 40 - 50 cms for pupation and by October majority of the grubs move below 70 cms in the soil. A small number may pupate in the begining

of November also. The time of pupation is linked with the time of egg laying. Some eggs which are laid in May and the larvae hatch out from these complete their development by late August or early September. Such larvae pupate in September. Since majority of eggs are laid after the regular monsoon rain received in late June or early July majority of the pupae are formed by the end of October. Therefore, in fields the pupae can be observed in the months of September, October and November (Table 6). The grubs prefer to pupate at an average depth of 45 cm in the month of September. Pupation in the subsequent months takes place at a deeper level in the soil. The depth of pupation is directly related to the soil moisture and temperature. It has been observed that as the time of pupation is more separated from rainy season and draws closer to the winter the pupation takes place at deeper level.

After completing their pupal stage in about 2 - 3 weeks new beetles are formed in the month of October and November. During these two months the beetles rest at the depth of 70 - 80 cm in the soil. In January they move further downwards upto 90 cm. From February onwards some upward movement may be observed, but upto the May they stay between 80 - 90 cm depth. During this period of about 7 - 8 months the beetles develop sexual maturity gradually and

the gonads are fully developed by the middle of May. Any rain received after middle of May, therefore, causes emergence of beetles. Rains received earlier than this may not cause emergence of beetles as they are not sexually mature for mating and egg laying.

Predators of Beetles - A number of predators are fond of feeding on beetles but all of these are not very effective in nature. The most efficient predators in nature are bats which prey upon the beetles during evening while they are flying from soil to the host. The bats can capture very effeciently the beetles during this period but this duration is very short i.e. of about half an hour. Once the beetles settle on hosts, bats are not able to capture them.

The birds like black Drango (Dicrurus macrocercus) stay late in the evening perching on wires or other points and capture some beetles. Blue jay (Coracias bengalensis) also behaves the same way. The cuckoo (Clamator jacobinus) also stays late in the evening and feeds on beetles of H. consanguinea, Anomala sp. and others. However, this duration is very short of about 10 minutes only as the birds are unable to stay active during darkness.

On ground, hedge hog feeds on beetles which fall on the ground. Toad though attempts and some time captures the beetles but lateron vomits out. The toad likes

smaller species of beetles such as Schyzonycha sp. Adoretus sp. and Maladera sp. etc.

Lizard (Varanus) feeds on beetles of H.consanguinea provided these are available on the ground surface.

During day time house sparrow can feed on beetles but in nature they cannot pickup any beetles.

Some dogs feed on beetles which fall on the ground beneath a lamp - post. The number of beetles fed by a dog varies from individual to individual. Some dogs eat a large number and then vomit them out, probably they are not able to digest.

CAUSES OF INCREASE IN WHITE GRUB POPULATION

The white grubs including that of H. consanguinea had been present in the Indian soils to varying numbers since very begining. The beetles were mostly feeding on forest trees and the larvae were surviving on the leaf littre of forest trees and roots of grasses. Due to deforestation they gradually moved out to the cultivated area and started feeding on the roots of crops. During last 15 - 20 years the population of this pest, has been increasing at a relatively faster rate but prior to this it was regulated at certain levels due to following factors.

i) Smaller area under cultivation and irrigation.

ii) Irregular monsoon, that is, a year of good rains followed by one or two years of drought. The drought used to cause heavy mortality of grubs because during drought neither the crop nor the grasses were able to survive, therefore, the larvae underneath the roots of these plants also become dried before completing their life cycle.

iii) Effective predation of grubs by the birds following the plough. Since the area under cultivation was small, there was enough number of predatory birds like Crows and Mynah to pick-up the grubs, exposed during ploughing of the field and thereby, reducing the population of grubs during the subsequent year.

iv) Less area under summer fodder crops - The summer crops provide suitable soil and food conditions for the survival of the grubs but because of small area under such crops very small population of beetles could survive in these fields.

Factors responsible for increase in the population of *L. consanguinea* during last 15 - 20 years:

i) Increase in the area of loamy sand soils under cultivation - This type of soil was lying uncultivated and therefore, not providing any food for grubs.

The cultivation of rainfed crops in these areas provided food for the larvae and thus helped in the population increase.

ii) Availability of better irrigation facilities. In the loamy sand soil regions during last 15 years there has been a considerable increase in the irrigation facilities in the form of canals, tube wells and pumping sets. A large area of cultivated land has been brought under irrigation which has ensured the survival ofthe crops in these areas even during drought, such a condition guaranteed the supply of food to the grubs and helped a large number of them to complete their life cycle in a larger area.

iii) Reduction in the number of predatory birds in general and per unit cultivated area in particular - It has been a common observation that the population of predatory birds like Crow and Common Mynah is gradually decreasing. The Crow in particular has been victim of higher human population which has made the nesting and roosting sites of the Crows unsuitable. The reduction in population of Crow, which is a very efficient predator, has contributed towards the survival of a larger number of grubs. Assuming that there has been no reduction in the population of such predatory birds, because of the increase of the cultivated area the number of birds available for

predation per unit area has gone consid

predation per unit area has gone considerably down. There are situations w[illegible]ly few or some times no bird is seen following the plough in the fields which are away from the village. It has been observed that 60 - 70%, of the grubs present in the soil can be picked-up by the predatory bird if ploughing is done in the month of August. Thus the reduction in the number of birds per unit area of cultivated land has been one of the major contributing factors in the increase of population of the pest.

iv) Tractor ploughing using discs - In sandy soils tractors fitted with disc plough are commonly used for tilling the soil. These discs do not expose the grubs to be preyed upon by the birds. Though it has been mentioned that some of the grubs get chopped off by the discs but the number of such grubs is likely to be the less than the number to be exposed to the predatory birds.

v) Cultivation of summer crops particularly fodder in relatively larger areas - The amount of food (root) provided by the summer fodder crops is much larger than other rainy season crop. Such crops provide food for a very large number of grubs per unit area and are very suitable for the egg laying and survival

of grubs of those beetles which emerge following the premonsoon rain. Since the area under summer crops has increased in [illegible] better irrigation facilities, these fields are working as centres of breeding of white grub.

During surveys it has been observed that white grub problem is not uniformly distributed in the entire area but is localised and centres around pumping sets and other irrigated patches. In Rajasthan there was good monsoon during the past 4-5 year's upto 1979 and therefore, a tremandous increase in the white grub population occured. The year 1979 was a drought year and therefore, there has been the reduction in the population of grubs during 1980 in the rainfed areas. However, relatively higher population is being observed around the pumping sets where the crops could be grown successfully during the drought.

It is, therefore, obvious that the changing cultivation practices, coupled with the above mentioned factors have contributed towards the increase in the population of white grub.

CONTROL

To achieve efficient suppression of population, the white grub control should be attempted in relatively larger areas or pockets instead of small fields or plots.

Therefore, all farmers of the infested area should adopt the appropriate control practices on their fields at the same time individually or in groups for several years in continuation and should not depend on outside agencies for various operations on their fields. However, some common arrangement should be made to suppress the pest population thriving on roadside trees, uncultivated lands and other public places. For this, help of Governments, Universities and other private organizations should be sought.

Following practices should be suitably integrated and adopted depending on the suitability and feasibility in the areas of operation:

(A) Control of beetles:

i) Mechanical control - The beetles can be easily collected during nights, after they settle on host trees, by shaking the branches of such trees with bamboo sticks. The collected beetles should be destroyed either by burning or by putting them in kerosinized water. This operation should be done every day after their emergence and should be continued till the beetle emergence is stopped.

ii) Chemical control - In cases where manual collection of beetle is not possible, the host trees should be sprayed during the day with 0.2% Carbaryl or 0.4% DDT or .05% Monocrotophos or .03% Quinalphos.

iii) Physical control - A small percentage of beetles of H. consanguinea and H. serrata area attracted toward light. Such beetles can be trapped by fixing light traps at suitable points.

(B) Grub Control:

i) Cultural

a. Two ploughing of fallow fields or summer fodder fields be given in the month of August to expose the grubs to predatory birds. If the population of birds following the plough is not sufficient, grubs may be collected manually and destroyed in kerosinised water. Some grub can also be out or damaged by disc during Tractor ploughing hence, this may be done during August wherever feasible.

b. Collection and destruction of grubs during intercultural operations be attempted. Use of grub puncture probe may prove very efficient for this purpose in crop like groundnut.

c. Flooding of fields, wherever feasible may be attempted.

d. Some crops toterate higher grub population under their rootzone as compared to other. For example Bajra, Jowar or Maize can be grown with very little damage for one or two years in areas where groundnut crops suffers

70-80% loss. However, in the subsequent years, by growing such crops the pest population will increase and these crops too will suffer heavy loss. Hence, it should be integrated with other methods and should not be practiced alone.

iii) Chemical control:

Following insecticides should be incorporated in soil furrows as presowing treatment:

1. BHC dust 12 kg a.i/ha
2. Phorate granules 2.5 kg a.i/ha
3. Quinalphos Granules 1.25 kg a.i/ha.
4. Sevidol 4:4 G 25 kg/ha.
5. Mixture of BHC + FYM (60 kg BHC 10% dust + 40 kg FYM) in furrows. Application of BHC be avoided in groundnut. It leaves undesirable residues in harvested pods.
6. Coating of seed (Groundnut only) with a slurry of Phorate + Clay at the rate of 1 kg ai/80 kg seed) is as effective as Phorate 3 kg ai/ha soil application.

The grub control of soil application of insecticide should be attempted in areas where beetle control could not be done. These two should not be integrated.

iv) Legal Control

Legislations should be brought in force to undertake, beetle control in all the infested areas and it should be made compulsory for all cultivators to execute the operation within specified time.

STRATEGY AND ORGANISATION OF WHITE GRUB CONTROL CAMPAIGN AT VILLAGE RATOLI, DIST. NANDED, (MAHARASHTRA STATE)

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Since 1970, the white grub (Holotrichia serrata Fab.) is posing a threatening problem to the cultivators in some of the endemic pockets of Maharashtra State. Approximately, 54 thousand hectares of the area is infested by this pest (Raodeo and Deshpande, 1974). Its infestation is spreading rapidly to the adjoining areas. At present three endemic pockets are located in the State, one in Nanded district, second in Buldhana and third in Sangli dist.

Crop losses to the tune of 30 to 80 per cent are noticed in the endemic pockets (Anon, 1973).

RESEARCH WORK CARRIED OUT AT MARATHWADA AGRICULTURAL UNIVERSITY, PARBHANI

Biology and control of Holotrichia serrata F. was worked out in the Entomology Department of Marathwada Agricultural University, Parbhani since 1971. Females lay 40-100 eggs, 7 to 12 cm deep in the soil during the months of June, July and August. Pearly white oval eggs, hatch in about 8 to 10 days. Newly hatched larva is tiny and milky white. Full grown larva (grub) is 3 to 5 cm long, 1 cm broad and fleshy, whitish or greyish white and

the body is curved in the form of letter 'C'. Larval period persists for about eight months.

The larvae undergo pupation, 20 to 40 cm deep in the soil in earthen cells in the months of March and April. Pupal period lasts for about 2 to 3 weeks.

Adults emerge out and remain in the soil till the onset of monsoon. Adults are about 2 cm long, 1 cm broad, reddish or blakish red or dark tan in colour (Majumdar, N., Teotia, T.P.S., 1965; Veeresh, G.K., 1977).

Field observations, for the behaviorial studies of adult beetles, at Kaothan and Ratoli villages in Nanded area indicated thatthe first emergence of the beetles takes place in the first week of June afterthe onset of monsoon. It was noticed that the beetles congregate in large numbers on babul trees (Acacia arabica Willd) at sunset and feed on their leaves throughoutthe night.

Early in the morning all beetles return to the soil. Babul trees predominantly found in this region preferred host of adult and gather on neem trees.

The adult population starts declining from the first week of August and disappears by middle of August.

Mechanical Control:

These beetles are not attracted towards light. After settling of these beetles on the babul and neem trees they become less active and if the plants are shaken they fall on the ground.

These beetles could easily be hand picked and killed in kerosenized water. This behaviour of the adult beetles gave a clue for the mechanical collection of beetles.

Chemical Control:

In order to find out the efficacy of insecticides for the adult beetles, laboratory experiment was conducted with DDT 0.4 per cent, Parathion 0.2 per cent, Endrin 0.1 and Carbaryl 0.1 per cent. It was observed that all the insecticides gave 100 per cent mortality within 72 hrs.

With a view to study the percentage kill of the full developed third instar larvae by the application of the insecticides in the soil, a laboratory trial was undertaken in wooden boxes of 1.22 x 1.22 m. size with BHC 10 per cent dust at 125 kg per hectare, Chlordane 5 per cent dust @ 65 kg per hectars and phorate 10 per cent granules @ 1 kg a.i. per hectare. This study revealed that only 30 per cent mortality of grubs was observed in BHC and phorate treated boxes and in other cases the mortality was still poor. Majority of the larvae escaped the contact

of insecticide and pupated in earthen cells upto a depth of 0.46 metre. Further studies made to protect the crop indicated that 10 per cent BHC dust at 125 kg per hectare gave significant protection of the crop.

Hence, the strategy to control the white grub is two fold: (1) mechanical collection and killing of adults (2) application of insecticide to kill grubs and spraying the babul and neem trees with 0.4 per cent DDT or 0.1 per cent Carbaryl.

DETAILS OF WHITE GRUB CONTROL CAMPAIGN

On the basis of the above research findings a scheme, to control white grubs, was submittedto the Government of Maharashtra by the Marathwada Agricultural University, Parbhani. Accordingly the Government accorded sanction for Rs.2.38 lakhs and gave a clearance to this scheme on 9th May, 1974.

Working of the Campaign:

On the receipt of the report of beetle emergence on 23rd May, 1974 from the survey party of the Entomology Department a training programme was organised at Ratoli on 26th May, 1974 to educate the farmers for the mechanical collection of the beetles by the Marathwada Agricultural University, Parbhani. Similarly a training was also organised on 3rd June, 1974 for the staff engaged in the campaign.

The cultivators were also induced for the collection of beetles by paying them a paisa per beetle. This operation was continued till the first shower on 7th June, 1974 i.e. till the emergence of beetles in large number.

Plan for Execution:

The village was divided into five units for the efficient and smooth execution of the campaign. For each unit a team of 15 to 20 cultivators along with 4 staff members were made responsible for mechanical collection of beetles, spraying of trees and soil application of BHC.

Mechanical collection of the Beetles:

In the beginning of the campaign more stress was given on the mechanical collection of the beetles. Every day at 7.30 p.m. five teams used to proceed to their respective units for the mechanical collection of the beetles. Each team was provided with two to three petromaxes, two pairs of gumboots, two torches, one match-box, four to five additional mentals and two containers along with the kerosinised water for the collection and killing of the beetles. On an average 10 labourers were engaged every day for the mechanical collection of beetles, besides the voluntary participation of the cultivators.

For the collection of the beetles, one to two persons used to climb the babul and neem trees and shake the branches.

The fallen beetles used to be collected and killed by puttingthem in kerosinised water. Regular records of the collected beetles was maintained. In the beginning there was less emergence of beetles (500 beetles/unit) and hence each team used to cover the entire area of his unit for the mechanical collection of the beetles. However, from 9th June, onwards the team could cover a fraction of the area only as there was heavy emergence of beetles after the showers on 7 and 8th June, 1974. On an average each team used to collect about one lakh beetles per day till the spraying of insecticide on the trees (19th June, 1974).

Spraying of Trees:

For spraying operation, three units were formed. In each unit one Agricultural Officer was made incharge of the spraying operation. He was assisted by two Agril. Assistants and one mechanic. Each unit was provided with one bullock cart, 4 drums (200 litres), 2 Hatsuta power sprayers, 2 to 4 Aspec-bolo power sprayers, and on an average 15 labourers.

The first spraying operation started from 19th June, with 0.08% endrin and continued till 21st June, 1974. From 22nd June onwards, DDT 50% W.P. was sprayed with concentration of 0.4% till 10th July, 1974. Rains interrupted the spraying operations from 27th June to 5th July, 1974. In the first spraying about 1000 acres (i.e. about 5600 trees

were covered by sprayingendrin at 0.08% concentration and the rest of the area i.e. 1200 acres (i.e. about 6400 trees) was coveredby spraying DDT at 0.4% concentration.

Second spraying started from 11th July, 1974, with DDT 50% and continued upto 11th July, 1974. Subsequently, spraying operations were discontinued as the area was inaccessible due to heavy rains and as such only an area of about 300 acres could be sprayed in second spraying.

Application of BHC 10% dust to Soil :

About 1703 acres were covered with BHC 10% dust at 50 kg/acre before sowing.

EVALUATION OF THE CAMPAIGN

Pretreatment count of beetles :

The population of the beetles in the endemic area was estimated by openic 50 pits (1x1x1 M) before spraying during the month of June, 1974. The average population of beetles per section was 5.88 per pit. On the basis of this sampling the population of the beetles was estimated to be 51,508,800 over an area of 876 ha in the village.

Population reduction of the beetles :

During the course of adult collection until 14th July, 1974 about 8,867,125 beetles were destroyed accoun-

ting 17.21% reduction out of the estimated beetle out of 51,508,800 beetle estimated.

The population of the beetles as recorded for five trees from each section in the insecticide treated and untreated areas (Table 1) showed that the percentage mortality of the beetles was significantly superior in the treated as compared to the untreated areas. From the results it was evident that the average number of beetles per tree in the untreated village of Salgara was 177 as against 19 beetles per tree which were recorded in the treated area of Ratoli. In addition, it was observed that there was 88% mortality in the population of the beetles on the trees where spraying with DDT was undertaken.

Plant population and yield in treated and untreated areas:

The plant population of various crops from 25 plots in the treated area of Ratoli and 25 plots from an untreated area at Karla were recorded at intervals of 15 days starting a fortnight after germination. Statistical analysis of the data indicates that the plant stand in the treated area is significantly greater than that in the untreated area.

Yield data from 25 treated and 25 untreated plots (selected for recording plant population), were analysed and an increase of 164, 102, 27.8 and 12.7% in rice,

chillies, cotton and jowar, respectively were recorded.

Population of white grub in treated and untreated area:

Observations of the population of the white grub larvae in the soil were recorded after the harvest of the crops in treated and untreated areas. Statistical analysis of the data showed that there was a significant reduction (80)% in the white grub larval population in the treated area when compared with the untreated area.

Conclusion:

The campaign contributed significantly to the control of the white grub at Ratoli. The effects of the campaign lasted over a year.

Suggestions and Modifications:

For the implementation of such a campaign in future the following suggestions and modifications may be taken into consideration:

1. Endrin should not be used for spraying the trees to control the beetles, as this insecticide is highly pisonous to non-target animals.

2. Wherever the campaign is organized the arrangement for the medical aid should be made as during the mechanical collection as well as during the spraying

operations chances of the accidents due to snake bites, poisoning etc. are more.

5. The persons engaged in the mechanical collection may be provided with the gum boots to give protection from snakes, scorpdons, thorns, mud etc.

4. For spraying high trees of 30 to 40 ft. height the hatsuta trolley mounted sprayers have been found very effective.

Economic threshold of white grubs based on adult population:

The experience gained during the collection of the above data revealed that when the population of white grub beetles was on an average 19 beetles per tree (16,31,750 beetles in an area of 876 hectares having 12,000 host trees) the mechanical collection was feasible in covering the entire area. But when the beetles population increase to thousands only about one fourth of the area of the village could be covered under mechanical collection (53,14,350 beetles on an average population intensity of beetles per tree was 1771), and as such the spraying was imperative.

The economics of the mechanical collection and spraying operations was carried out from the data collected during the implementation of the white grub control

campaign. It was revealed that the per acre expenditure incurred towards mechanical collection on an average was Rs. 1-30, where as the same towards spraying operations was Rs. 9-00. Hence, mechanical collection stands superior to chemical control not only from the economical point of view but also from the pollution point of view.

Hence, tentatively the economic threshold of white grubs based on adult population is fixed at 20 beetles per tree on an average.

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STUDIES ON THE BIONOMICS OF WHITE GRUB HOLOTRICHIA SERRATA F

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Since 1973, white grub is posing a threat to the cultivators in some endemic pockets of Maharashtra State. This post has become serious in Ahmednagar, Buldhana, Dhule, Jalgaon, Kolhapur, Osmanabad, Parbhani, Sangli, Satara and Wardha districts of Maharashtra State, where sometimes 100 per cent losses in kharif crops are noticed damaged on Jowar, Sugarcane, Paddy, Groundnut, Chilli, Sunflower, Brinjal, Bajra, Potato and Tobacco.

An attempt has been made to study the bionomics of Holotrichia serrata F, the species responsible for the damage.

Host plants :

The beetles were seen feeding on the leaves of Neem and Babhul trees as reported earlier by several workers. However, they were found feeding on the leaves of the Gulmohar trees also in Maharashtra State.

The grubs eat away nodules of leguminous plants and the fine Rootlets and girdle the main root. Due to this type of damage groundnut and tobacco plants which have a tap root system are highly susceptible to grubs,

whereas, plants like sorghum, Bajra, maize having adventitious root system can withstand larger grub population.

Life history :

(a) Emergence :

The emergence of the beetles from the soil starts after receiving about 33 mm rain in monsoon or premonsoon season. The emergence starts in the evening at a specific light intensity and completes within about 10 to 15 minutes, during 7.20 pm to 7.50 pm.

(2) Copulation :

The emerged beetles settle on the host trees of neem and babhul and immediately mate. During mating the female clung to the leaves, while the male moves on the elytral portion of female with its head and take opposite position to the female. The mating lasts for about 5 to 11 minutes. Observation made on the mating behaviour showed that the same pair of male and female do not mate repeatedly. After the mating is over they start feeding. They remain active during the night and migrate to the soil usually between 5.40 to 6.00 a.m. the migration is completed within 4 to 10 minutes.

(3) The behaviour of beetles :

Marked beetles on the marked bushes goes on decreasing by about 60% in the succeeding days, however, unmarked beetles were seen every night on marked bush.

In the beginning of the emergence i.e. in May and June the ratio of male and female beetles was 3:1. In the month of July it was 1:1. The emergence decreased during August.

Once a beetle starts feeding on a tree generally it remains on the same tree throughout the night.

Eggs :

Adult beetles lay eggs singly with jelly like white substance in soil to a depth of 10 cm. However, upto five eggs were found in an earthen cell and a maximum of 14 eggs were laid in a day by a single female. The freshly laid egg is smooth milky white in colour and oval in shape measuring about 3.65 mm in length and 2.15 mm in width.

The oviposition continues through out adult life. As many as 50 to 60 eggs are laid by a single female. The moist sandy soil which is slightly raised and covered with vegetation or soil underneath the trees or bushes is preferred for the egg laying.

As development proceeds the egg increases in size. A part of egg becomes hyaline white and other part remain milky white. About 7 days after oviposition the developing embryo becomes visible. Prior to hatching, the egg is

smooth ellipitical and measures 5.33 mm in length and 4.05 mm in width.

Grub

Immediately after hatching the grub eats the egg shell, remains inactive for 2 to 3 hours and is milky white in colour with dirty white head, measures about 2.25 mm in width (at head) and 9.77 mm in length. After 3-4 hours the body expands and colour of the head becomes brownish, starts feeding on organic matter. On an average the first moulting takes place after 25.32 days with the minimum of 19 days and maximum of 59 days. The first instar requires more quantity of organic matter and very less quantity of roots.

The second instar grub measures on an average 36.5 mm in length and 3.85 mm in width of the head. The general morphological characters and colour pattern are similar to those in the first instar except that its last abdominal segment is enlarged. The duration of the second instar on an average is 37.42 days with minimum of 14 days and maximum of 62 days. The second instar is more curved, active and cannibalistic. During the first half of the second instar more quantity of organic matter and less quantity of roots are required and in the remaining half the period the reverse is the case of its food requirement.

The third instar grub is creamy white measuring on an average 46.50 mm in length and 6.60 mm in width of the head. The average duration of third instar is 143.12 days.

The grubs when fully grown cease feeding and dig down 10 to 15 cm depth construct cells, tend to shrivel up in preparation for a change to the pupal stage, and finally shed skin and change to pupae.

The Pupa:

The freshly formed pupa is creamy white but soon assumes a brown colour. The pupae are exarate and the pupal period varied from 20 to 24 days.

Majority of the grubs reach the adult stage before the onset of severe summer. These adults were found to pass the inactive period during summer.

A COMPENDIUM OF LITERATURE ON INDIAN WHITE GRUBS

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